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THE

JOURNAL

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NORMAL AND PATHOLOGICAL, HUMAN AND COMPARATIVE.

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Journal of Anatomy and Physiology.

THE CENTRAL CONNECTIONS AND RELATIONS OF THE TRIGEMINAL, VAGO-GLOSSOPHARYNGEAL, VAGO-ACCESSORY, AND HYPOGLOSSAL NERVES.

By WILLIAM ALDREN TURNER, M.D. (Edin.), M.R.C.P., *Demonstrator of Neuro-Pathology, King's College, and Assistant Physician, the West London Hospital.*[1]

RECENT investigations upon the central nervous system, by means of the osmium-silver method of Golgi, have supplied, among other facts, much that is new upon the connections and relations of the cranial nerve nuclei. This subject has received special attention at the hands of Kölliker[2] and Held[3] within the past two years. The object of this paper is more especially to retail these views in connection with certain of the cranial nerves, at the same time bringing to bear upon them some personal observations which have been obtained by this and other methods.

The methods which have been adopted are—

(*a*) Examination of the brains of newly-born kittens by the osmium-silver method of Golgi.[4]

(*b*) The study of the brain of an eight-months human fœtus from the point of view of medullation.

(*c*) Examination of the hind brain of monkeys after intracranial division of the nerve roots.

(*d*) Study of the cranial nerve nuclei in bulbar paralysis.

[1] An abstract of this paper was read before the Brit. Med. Association at Bristol, August, 1894.

[2] Kölliker, *Handbuch der Gewebelehre*, 1893.

[3] Held, *Arch. f. Anat. & Physiol. Anat. Abtheil.*, 1893.

[4] I am specially indebted to Dr Bulloch for the very fine preparations of kittens' brains which he prepared by Golgi's method, and for the sections of an eight-months human fœtus, stained by the Weigert-Pal method. In the experiments upon the brains of monkeys, I have been jointly associated with Prof. Ferrier, F.R.S. The work has been done in the Neuro-Pathological Laboratory, King's College, London.

As a preliminary to the more detailed description of the cranial nerve nuclei, the conclusions formed by Kölliker may be briefly stated. He has shown that these nuclei are of two sorts—nuclei of origin and nuclei of termination (endkerne) of root fibres. From the nuclei of origin there pass *efferent* root fibres, which are the axis-cylinder processes of the cells of the nerve nucleus. Towards the nuclei of termination there pass *afferent* root fibres, which are the axis-cylinder processes of cells in ganglia lying extra-cranially. Nuclei of origin have, however, *afferent* fibres passing to them from different parts of the brain; while nuclei of termination have *efferent* fibres conducting impulses to other and higher parts.

1. The Hypoglossal Nucleus.

The *hypoglossal chief nucleus* consists of a column of cells lying ventral to the central canal as long as this remains closed; but when it has opened out into the fourth ventricle, the nucleus forms the mesial part of the mass of grey matter forming its floor. The cells of the nucleus are roughly divided into three groups—internal, external, and posterior (Bruce). In sections prepared by the osmium-silver method the cells are seen to be large multipolar structures conforming to Golgi's first type. The axis-cylinder processes become chiefly the issuing roots of the nerve; while some pass to ganglion cells in the reticular formation (Held). A few processes are seen to cross the middle plane, so as to form a commissure between the two nuclei. This is best seen in Golgi preparations, but the commissure has also been observed in sections stained by other methods.

Within and around the nucleus are many medullated nerve fibres. In frontal sections through the medulla oblongata, the fibres lying upon the dorsal aspect of the nucleus are cut transversely, while those lying within and ventral to the nucleus are cut longitudinally. As will be shown later on, these fibres have different origins and connections. The majority of the dorsal fibres probably form the hypoglossal segment of the "dorsal lângsbundel" of Schütz;[1] the ventral group are passing to the nucleus from the posterior longitudinal bundles and raphé, while

[1] Schütz, *Archiv f. Psychiatrie*, 1891, p. 527.

those within the nucleus are partly the axis-cylinder processes of the hypoglossal cells, and partly the terminations of the afferent fibres of the nucleus.

The so-called *fibræ propriæ* of Koch[1] are regarded as chiefly pyramidal fibres, from the following facts: firstly, they had disappeared in a case in which atrophy of the cells of the hypoglossal nucleus was associated with sclerosis of the pyramids, while they were unaffected in a case in which the hypoglossal cells were alone atrophied; and secondly, they were not visible in an eight-months human fœtus in which the pyramids were as yet non-medullated, the other fibres of the nucleus being fully medullated.

Two accessory nuclei have been described in connection with the hypoglossal nerve—Roller's small-celled nucleus, and the nucleus of Duval.

1. *Roller's small-celled nucleus* lies ventral to the chief nucleus. According to the observations of Roller[2] and Koch (*op. cit.*) it gives origin to some root fibres of the hypoglossal nerve, but it is doubtful whether this is so. In two cases of bulbar paralysis, in which the cells of the chief hypoglossal nucleus were atrophied, the nucleus of Roller remained perfectly unaffected. In these cases the hypoglossal nerve roots were also completely atrophied.

2. *Duval's accessory nucleus*[3] consists of large multipolar first-type cells, lying in close relation to the roots of the hypoglossal nerve. According to Kölliker[4] it is divided into two parts—one lying amongst the root fibres, and perhaps giving origin to some of them; the other situated laterally, and having no relation to the roots.

An analysis of the records of published cases of bulbar paralysis, in which the state of these nuclei was specially noted, as well as my personal observation in two cases, indicates that they are not implicated in this disease. That they do not give origin to hypoglossal root fibres is also shown by the experiments of Mingazzini.[5]

[1] Koch, *Arch. f. Mikroskop. Anat.*, 1888, p. 54.
[2] Roller, *Arch. f. Mikroskop. Anatomie*, 1881.
[3] Duval, *Journ. de l'Anatomie*, 1876.
[4] Kölliker, *op. supra cit.*, p. 232.
[5] Mingazzini, *Annali di freniatria*, 1891.

Duval's nucleus appears to be one of the many groups of large multipolar cells which lie in the reticular formation and tegmentum; it is not unlikely, from its position relatively to the hypoglossal roots, that it is the upper end of the so-called respiratory nucleus of Misslawsky,[1] which is seen lying at the level of the fillet decussation, along the lateral margin of the anterior ground bundle as it passes backwards to become the posterior longitudinal fasciculus.

The physiological value of the nuclei of the reticular formation and tegmentum is still unknown. It is not improbable that many of the nuclei are stations in long commissural fibre systems uniting the cranial nerve nuclei with each other and with the spinal nerve nuclei. The nucleus of Deiters is undoubtedly, in part at least, a station in the cerebello-spinal system; and the observations of Held,[2] Boyce,[3] and others have shown the presence of long descending internuncial fibres between the superior corpora quadrigemina and the antero-lateral columns of the spinal cord.

The *efferent* hypoglossal fibres are the root fibres or axis-cylinder processes of the cells of the nerve nucleus. Atrophy of the cells of the nucleus, which occurs in the condition known as bulbar paralysis, is associated with atrophy of the root fibres in direct proportion to the amount of cell degeneration. In an eight-months human fœtus the hypoglossal nucleus and nerve roots were fully medullated, while the pyramidal fibres showed scarcely any medullation, showing that there is no *direct* prolongation of pyramidal fibres into the roots. The root fibres spring from the nucleus of the corresponding side. The experiments of Mingazzini (*op. cit.*) and Schäffer[4] negative the view that the hypoglossal nerve of one side receives directly axis-cylinder processes from the cells of the opposite nucleus: a connection may, however, exist indirectly through the commissural hypoglossal fibres already described.

[1] Misslawsky, ref. by Bechterew, *Die Leitungsbahnen*, &c., 1894, p. 58.

[2] Held, *Abhandl. d. Math.-Phys. Classe d. k. Säch. Gessellsch. d. Wissensch.*, No. vi., 1892. *Sep. Abdruck.*

[3] Boyce, *Proc. Roy. Soc.*, March 1894, p. 269.

[4] Schäffer, referred to by Bechterew (*op. cit.*), *Inaug.-Dissertation*, Erlangen, 1889.

The *afferent* hypoglossal fibres come from several sources:—

(*a.*) Pyramidal fibres, connecting the cells of the cortical centre for the movements of the tongue with the hypoglossal nucleus. These fibres pass from the pyramids of the medulla dorsally into and through the raphé, to terminate in end-tufts in relation to the cells of the nucleus. In the cases of sclerosis and atrophy of the pyramids, both unilateral and bilateral, which I have examined, there was, however, no clear evidence of any tract of degeneration in the medullary raphé. The majority of the raphé fibres are derived from other sources, the chief of which in this region are the nuclei of the reticular formation and the end-nucleus of the fifth nerve (substantia spongiosa). In an eight-months human fœtus in which the pyramids were non-medullated, the *fibræ propriæ* of the nucleus were still without their medullary sheaths.

(*b.*) Fibres from the fillet come, according to Kölliker, into relation with the hypoglossal nucleus. In normal sections through this region fibres are seen bending out of the raphé, and passing between the nucleus and the posterior longitudinal bundle. Some of these fibres enter the nucleus, while others may be followed to its lateral aspect. The presence of such fibres is undoubted; and that they are not pyramidal fibres is probable from the facts that, firstly, they were clearly seen in a case in which both pyramids were sclerosed, and, secondly, they were well medullated in an eight-months human fœtus in which the pyramidal fibres were non-medullated. I am as yet unable to determine whether they are really fillet fibres, for, in a case in which the fillet was degenerated, these fibres did not appear to be materially altered. That they are not efferent hypoglossal fibres is evident from their intact condition when the cells of this nucleus have entirely disappeared.[1]

(*c.*) Fibres from the grey reticular formation, the "sensible" hypoglossal fibres of Kölliker. The existence of these fibres appears to have been largely overlooked, but they are present in considerable numbers, and are especially well seen in cases of bulbar paralysis where the *issuing* roots of the nerve have disappeared. Their origin is, according to Kölliker, in the reticular formation, but it is as yet impossible to say whether

[1] This has also been noticed by Mingazzini, *op. supra cit.*

they are collaterals of long commissural systems in transit through the medulla, or whether they arise in cells scattered throughout that formation. It seems most probable that they are associated with the reflex mechanisms of the tongue.

A direct connection between the cells of the hypoglossal nucleus and the issuing vagus roots has been described by several observers (Lockhart Clarke,[1] Bruce,[2] and others), and it has been suggested that this may be a source of innervation for the muscles of the soft palate and of the vocal cords. It seems more probable, however, that these fibres are really efferent vago-glossopharyngeal fibres passing from the cells of the posterior nucleus into the hypoglossal nucleus where they terminate in end-tufts (Kölliker[3]).

2. The Vago-glossopharyngeal and Vago-accessory Nuclei.

These nuclei, which are considered as segments of one structure, are composed of two parts—an anterior and a posterior: the former is the origin of the motor (efferent) root fibres of the vago-glossopharyngeal-accessory nerves, and forms the so-called *nucleus ambiguus;* the latter is the end-nucleus of some of the afferent fibres of the vago-glossopharyngeal nerve roots.

(*a.*) *Nucleus ambiguus.*—According to Kölliker, to whom we are indebted for a very full and clear account, this nucleus extends from the level of the fillet decussation, proximally as far as the exit of the upper glossopharyngeal root fibres. It is, therefore, coextensive with the posterior division of the nucleus, but occupies an antero-lateral position in the medulla. It is recognised by the position of its cells, which lie *upon* and *mesial* to the vago-glossopharyngeal root fibres. By the osmium-silver method it is found to be composed of large multipolar cells of Golgi's first type, the long axis of the cell lying parallel to the root fibres. From the fact that the nucleus alters its position in higher and lower portions of the medulla, it has to be carefully defined from the *nucleus antero-lateralis medullæ* and the *nucleus centralis inferior* respectively. The former, which in the

[1] Lockhart Clarke, *Phil. Trans.*, 1868.
[2] Bruce, *Illustrations of Mid and Hind Brain*, 1892.
[3] Kölliker, *op. cit.*, p. 247.

upper parts of the medulla lies immediately on its outer side, is characterised by the large amount of neuroglia in which its cells lie; the latter, in the lower parts of the medulla, lies mesial to the nucleus ambiguus.

The *efferent* fibres of the nucleus are the axis-cylinder processes of its cells. In the lower portion of the medulla these fibres pass directly outwards from the nucleus as the roots of the vago-accessory nerve, while in the upper portion they assume a dorso-internal direction before bending outwards as the motor fibres of the vagus and glosso-pharyngeal nerves (Kölliker).

In many cases of bulbar paralysis the cells of this nucleus have been found atrophied. But whether atrophy occurs at all, or is only slight, depends upon the amount of nuclear involvement and the stage of the disease at the time of death. A comparison of the clinical symptoms in this disease with the pathological facts indicates that the nucleus ambiguus is the nucleus of origin of the motor fibres for some of the muscles which move the vocal cords (*e.g.*, m. thyro-arytenoideus internus), and probably also for the levator palati muscle.[1]

The *afferent* fibres of the nucleus are less well known. Undoubtedly pyramidal fibres pass to it, but their position and course is as yet uncertain. Kölliker also mentions a connection between this nucleus and the posterior vago-glossopharyngeal column, the sensory root of the trigeminus, and the longitudinal fibres of the grey reticular formation.

(*b.*) The *posterior vago-glossopharyngeal nucleus* is the end-nucleus (endkern) of some of the afferent fibres of the combined vago-glossopharyngeal nerve (Kölliker and Held[2]). The roots of this nerve are composed of two kinds of fibres: firstly, those efferent fibres which have been already shown to arise in the nucleus ambiguus; and secondly, afferent fibres which are the axis-cylinder processes of the cells situated in the jugular and petrosal ganglia and the ganglia of the vagus (Kölliker). This

[1] Pathological evidence in favour of this view is obtained from cases of bulbar paralysis, where during life paralysis of the soft palate and of the internal thyro-arytenoid muscles was observed, and on post-mortem examination atrophy of he nucleus ambiguus was detected. Oppenheim, *Arch. f. Psychiatrie*, 1892, p. 758; Turner and Bulloch, *Brain*, No. 68.

[2] Held, *Arch. f. Anat. & Physiol.*, *Anat. Abth.* Hft. 5 and 6, p. 435.

observer has further shown that these afferent fibres break up into end-tufts in the posterior vago-glossopharyngeal nucleus.

In osmium-silver preparations many cells of this nucleus are multipolar, and conform to the first type of Golgi, but they are distinctly smaller than those of the hypoglossal nucleus and nucleus ambiguus, and are usually spindle-shaped. Held (*op. cit.*) has also observed cells conforming to Golgi's second type,—that is, cells whose axis-cylinder process does not leave the grey matter of the nucleus, but breaks up into a number of fine branches.

In two cases of bulbar paralysis in which the condition of the nucleus was specially investigated, the cells were found to be perfectly normal.

The *afferent* fibres of the nucleus have been already shown to be the axis-cylinder processes of the cells in the ganglia upon the glossopharyngeal and vagus nerves.

The *efferent* fibres are the axis-cylinder processes of the cells composing the nucleus. The connections of these fibres are as yet uncertain. Kölliker has found both in Golgi and Weigert preparations fibres passing into the fillet layers. It seems probable that some fibres may also pass into the hypoglossal nucleus, while others crossing the raphé enter the posterior longitudinal bundle of the opposite side; other fibres, as were seen in osmium-silver preparations of the kitten's brain, passed into the reticular formation, where they were lost to view.

(*c.*) *The Fasciculus solitarius, or ascending Glossopharyngeal Root.*—A third factor is to be studied in connection with the vago-glossopharyngeal root fibres. According to His and Kölliker, the fasciculus solitarius derives its fibres from both the ninth and tenth nerves. This bundle is traced from the level of the uppermost glossopharyngeal roots as far as the lower end of the medulla oblongata. Bruce (*op. cit.*, p. 5) localises its lower end in a group of cells situated dorso-externally to the posterior vago-glossopharyngeal nucleus in front of the funiculus gracilis. Surrounding this bundle, which is composed of axis-cylinder processes and their collaterals, is a considerable amount of gelatinous substance, into which the fibres pass and terminate (Kölliker). In the gelatinous substance are found cells which send their processes into the reticular formation, and in this way they associate the fasciculus solitarius with other parts of the brain.

The following observations have been made *a.* from sections of the medulla oblongata of a monkey, in which the glosso-pharyngeal roots were divided as they issue from the brain, and *b.* from a series of sections of the medulla of a new-born kitten prepared by Golgi's method.

Division of the glossopharyngeal nerve roots was followed by degeneration of many of the intra-medullary root fibres: these could be traced both into the fasciculus solitarius and to a less extent into the posterior glossopharyngeal nucleus. The whole of the fibres of this so-called ascending root were not degenerated, supporting the view of His and Kölliker, that some fibres are derived from the vagus roots. At the level of the fillet decussation the degenerated bundle was found lying in the reticular formation external and ventral to the internal arcuate fibres: the caudal termination of this structure is still the subject of investigation.[1]

Entire corroboration of Kölliker's statements resulted from examination of the osmium-silver preparations. The fasciculus solitarius is by this method seen to be surrounded chiefly on its mesial aspect by gelatinous substance very rich in end-tufts, into which the fibres of the bundle have broken up. Amongst the end-tufts are seen cells chiefly of the second type, whose axis-cylinder processes branch and pass into the reticular formation.

From these observations it is seen that the so-called ascending glossopharyngeal root is analogous with the so-called ascending trigeminal root, both of which are composed of *afferent* fibres, passing to their end-nuclei, and springing from the cells of ganglia which are situated extra-cranially.

3. Trigeminal Nerve.

The central connections and nuclei of this nerve are considered under two heads :—

(1) The sensory division, including the so-called "ascending" trigeminal root; and (2) the motor division, embracing the so-called descending root.

[1] Krause, who named this the "respiratory bundle," traced it as far as from the fourth to the eighth cervical nerves. Kölliker, who has re-examined some of Krause's preparations, is of opinion that the bundle so named in this situation belongs to the roots of the spinal accessory nerve (*op. cit.*, p. 248).

1. The *sensory division* of the nerve may be readily traced amongst the fibres of the middle cerebellar peduncle into the lateral part of the tegmentum pontis. Here some fibres pass directly into the so-called sensory nucleus (convolutio quinti), which is nothing else than the expanded proximal termination of the substantia gelatinosa Rolando (Kölliker and Bruce). The remainder of the division is followed through the pons Varolii and medulla oblongata, in the distal part of which it forms the layer of white matter covering the gelatinous expansion or tubercle of Rolando. The recent observations of Kölliker and Held, working by Golgi's method, show that the fibres composing this root are the axis-cylinder processes and collaterals of the cells of the Gasserian ganglion. Throughout its extent such fibres are being given off into the gelatinous substance, to terminate in end-tufts, which embrace cells lying in this region. These cells in turn give off axis-cylinder processes, which pass as arcuate fibres across the raphé, and entering the tegmentum of the opposite side, pass towards the cerebrum as longitudinal fibres. In this manner the *substantia gelatinosa Rolando* is regarded by these authors as the end-nucleus of the sensory trigeminal fibres, just as the *caput cornu posterioris* is the end-nucleus of the direct fibres of the posterior spinal roots, and the posterior vago-glossopharyngeal nucleus is the end-nucleus of some of the afferent vago-glossopharyngeal root fibres.

My own observations are in harmony with those above described. In well-prepared osmium-silver sections of a kitten's brain fine fibres were observed passing through the gelatinous substance into the substantia spongiosa, which forms its mesial concave aspect. Here, as also noted and figured by Kölliker (*op. cit.*, fig. 518), the best examples of end-tufts are to be seen; while lying mesial to this are multipolar cells of the first type, sending their axis-cylinder processes into the *formatio reticularis.*

The view that the substantia gelatinosa and spongiosa is the end-nucleus of the sensory trigeminal fibres receives corroboration by experiment.

Thus, section of the sensory trunk in Monkeys, or its implication by disease in Man,[1] and section of the ascending trigem-

[1] Tooth, *St Bart. Hosp. Reports*, 1893, p. 215.

inal root in the medulla oblongata, are followed by degeneration of the fibres of this root into or through the gelatinous substance of Rolando. It has not been found possible by the Weigert-Pal method to trace the degeneration beyond this into the tegmentum pontis; but Bregmann[1] states that he has observed by Marchi's method degenerated fibres in the reticular formation after section of the fifth nerve trunk proximal to the Gasserian ganglion.

The probability is, however, that the degeneration is arrested at the cells in the substantia spongiosa, which forms the end-nucleus of the nerve. The cells in this situation are difficult to stain by the ordinary methods in use; and in several instances in which the ascending root was sclerosed, I was unable to obtain any clear evidence of cell atrophy.

The *afferent* fibres of the sensory trigeminal end-nucleus (subs. gelatinosa or spongiosa) are therefore the axis-cylinder processes and collaterals of the cells of the Gasserian ganglion, which form the so-called ascending trigeminal root; the *efferent* fibres are the axis-cylinder processes of the cells situated in the end-nucleus, which pass into the reticular formation and cross the raphé.

2. *The Motor Roots.*—These consist of fibres, coming, on the one hand, directly from the cells of the motor nucleus, and on the other, of fibres from the descending trigeminal root.

The cells of the motor nucleus consist of large, multipolar, first-type cells, which send the axis-cylinder process directly into the motor root, and form the *efferent* fibres of the nucleus. A crossed connection has been described by many observers, and Kölliker confirms its presence in new-born animals. A very well-marked strand of fibres may sometimes be observed in the situation of the crossed root. These are, without doubt, the most proximal fibres of the *genu facialis*, and the issuing limb of that nerve, and have probably been mistaken for a crossed trigeminal root in some cases. The *afferent* fibres of the nucleus are the pyramidal fibres from the cerebral cortex, but their situation has not as yet been definitely determined. Arguing, however, from what occurs in the hypoglossal nucleus, these fibres probably reach the nucleus by way of the raphé and the reticular formation.

[1] Bregmann, *Jahrbuch f. Psychiatrie*, vol. xi.

The *descending trigeminal root* or trophic root of Merkel is still the subject of much discussion. It was for long disputed whether the root joined the motor or the sensory division of the nerve. Obersteiner,[1] Mendel,[2] and Bechterew[3] inclined to the latter view, which also found favour with Meynert;[4] but the more recent observations of Poniatowsky,[5] Bregmann,[6] Bruce,[7] Kölliker,[8] Boyce,[9] and others lend support to the view of Henle and Forel,[10] that it passes into the motor division of the fifth nerve.

Arising in large multipolar first-type cells (Kölliker) situated in the peripheral parts of the Sylvian grey matter as high up as the anterior corpora quadrigemina, the fibres of the root, which are axis-cylinder processes of these cells, may be traced distally to the lateral angle of the fourth ventricle at the level of the substantia ferruginea, where they form a characteristic crescentic tract of white matter, lying under cover of the superior cerebellar peduncle.

Of personal observations upon the functions and connections of this root, the following may be stated :—

1. In an experiment in which the motor root of the fifth nerve was destroyed in its course through the pons Varolii, atrophy of the fibres of the descending trigeminal root and of the cells from which they spring was detected.[11]

2. In an experiment upon the superior cerebellar peduncle, in which the descending root was divided where it lies under cover of this structure, degeneration of some of the fibres of the issuing motor root was observed, the motor nucleus itself being intact.

3. In an eight-months human fœtus, the passage of the medullated fibres of the descending root could be clearly traced directly into the motor division of the nerve.

[1] Obersteiner, *Central Nervous Organs* (Transl.), p. 295.
[2] Mendel, *Neurol. Centralb.*, 1888, p. 401.
[3] Bechterew, *Neurol. Centralb.*, 1885, p. 337.
[4] Meynert, quoted by Schwalbe, *Lehrb. d. Neurol.*, p. 680.
[5] Poniatowsky, *Jahrb. f. Psych.*, vol. xi. Ref. in *Neur. Centralb.*, 1892.
[6] Bregmann, *Jahrb. f. Psych.*, vol. xi. Ref. in *Neurol. Centralb.*, p. 780., 1892.
[7] Bruce, *Illustrations of Mid and Hind Brain*, 1892, p. 156.
[8] Kölliker, *op. supra cit.*, p. 291.
[9] Boyce, *Journ. of Physiol.*, 1894, p. 156.
[10] Henle and Forel, quoted by Schwalbe, *op. cit.*, p. 680.
[11] Ferrier and Turner, *Proc. Roy. Soc.*, vol. 54, p. 476.

These observations therefore corroborate the view that the descending root joins the *portio minor* or motor division of the trigeminal nerve.

It is more difficult to determine what is really the function of the root.

The original view of Merkel[1] (1874) that it was the trophic root of the fifth nerve was based on very insufficient grounds, and was distinctly negatived by experiments carried out by Eckhard[2] two years later. Merkel's view has, however, recently received support at the hands of Mendel,[3] who observed atrophy of the descending trigeminal root in an old-standing case of facial hemiatrophy. More recent observations, however, would seem to show that this root, in part at least, has motor functions. Kölliker (*op. cit.*, p. 291) states that this root probably supplies motor fibres for the *tensor palati* and *tensor tympani* muscles, and this view receives corroboration from the experiments of Réthi,[4] on stimulation of the motor root of the fifth within the cranial cavity. My own observations have been made on the pathological appearances in bulbar paralysis, and on section of the root in Monkeys. In a case[5] in which, during life, the muscles of mastication were paralysed, the motor nucleus of the fifth was afterwards found almost completely degenerated. On the other hand, the fibres of the descending root, and the cells from which they spring, were quite normal, which observation eliminates the possibility of a motor supply by this root to the muscles of mastication, at any rate in Man.

In opposition to the view of Merkel, and in harmony with Eckhard's experiment, division of this descending trigeminal root was not followed by any detectable trophic alteration in the eyeball.[6]

The existence of a *cerebellar root of the trigeminus*, which was described by Meynert and others, has not been corroborated by more recent investigators (Bechterew,[7] Poniatowsky[8]). According-

[1] Merkel, *Untersuch.*, &c., Rostock, 1874.

[2] Eckhard, *Ueber die trophische Würzel des Trigeminus: Beiträge*, No. 7, 1876, p. 143.

[3] Mendel, *Neurol. Centralb.*, 1888, p. 401.

[4] Réthi, *Centralb. f. Physiol.*, 1893, p. 515.

[5] Tooth and Turner, *Brain*, 1891, p. 473.

[6] Ferrier and Turner; unpublished experiments.

[7] Bechterew, *Die Leitungsbahnen*, &c., 1894.

[8] Poniatowsky, *Jahrbuch f. Psychiatrie*, vol. xi.

ing to Edinger,[1] this is the trigeminal portion of a "direct sensory cerebellar tract," connecting the auditory and vago-glossopharyngeal nerve roots with the cerebellum. After section of the sensory division of the fifth nerve, no tract of degeneration was observed passing up into the cerebellum; but, on the other hand, after extirpation of the *vermis cerebelli*, an area of degeneration in the position of this cerebellar root was observed, and its termination was found in the nucleus of Deiters, or large-celled external auditory nucleus.[2] The cerebellar root of the trigeminus, therefore, appears to be a portion of an efferent tract from the middle lobe of the cerebellum.

SUMMARY.

The general conclusions which may be drawn from the foregoing facts and observations are—

1. That the hypoglossal nucleus is solely a nucleus of origin; that the *efferent* fibres are the axis-cylinder processes of the cells of the nucleus of the corresponding side, and have no direct connection with the opposite nucleus, or with the nuclei of Roller and Duval; and that the *afferent* hypoglossal fibres are derived from the pyramids, forming in chief part the *fibræ propriæ*, also from the reticular formation, and possibly from the fillet.

2. That the *nucleus ambiguus* is the nucleus of origin of the motor fibres contained in the roots of the glosso-pharyngeal, vagus, and vago-accessory nerves, and innervates, among other structures, the levator palati and internal thyro-arytenoid muscles. The *afferent* fibres of the glosso-pharyngeal and vagus roots are the axis-cylinder processes of the ganglia upon these nerves, which terminate in the posterior vago-glossopharyngeal nucleus and in the gelatinous substance around the *fasciculus solitarius* (Kölliker). These facts are confirmed by observation of cases of bulbar paralysis, and by experimental section of the glosso-pharyngeal nerve roots. The latter was followed by degeneration of the solitary bundle, or so-called ascending glossopharyngeal root. These structures therefore form the nuclei of termination of the combined vago-glossopharyngeal nerve.

[1] Edinger, *Zwölf Vorlesungen*, 1892, p. 118.
[2] Ferrier and Turner, *loc. supra cit.*

3. The *substantia gelatinosa* and *spongiosa*, situated in the lateral parts of the medulla oblongata and pons Varolii, forms the end-nucleus of the so-called ascending trigeminal root, the fibres of which are the axis-cylinder processes of the cells of the Gasserian ganglion (Kölliker). Section of the sensory division of this nerve is followed by degeneration of the ascending root through the gelatinous substance into the *substantia spongiosa*, where the fibres break up into end-tufts. In this situation are cells, chiefly of Golgi's first type, whose axis-cylinder processes pass into the reticular formation.

4. The motor nucleus of the fifth nerve is the nucleus of origin of most of the fibres of the motor root, the fibres being the axis-cylinder processes of the large multipolar cells of the nucleus.

5. The so-called descending trigeminal root is composed of the axis-cylinder processes of the cells in the outer part of the Sylvian grey matter, and joins the motor division of the nerve. It is not improbable that this nucleus innervates some of the muscles supplied by the fifth cranial nerve. It is not "trophic" in the sense used by Merkel.

6. There is no direct cerebellar root of the fifth nerve. What has previously been described as such is a tract of fibres passing between the roof nuclei and the nucleus of Deiters, and probably also between the superior olivary bodies and the roof nuclei of the cerebellum (Bruce).

ABNORMAL KIDNEYS FROM THE DOMESTIC PIG (*Sus scrofa*).

By DAVID HEPBURN, M.D., F.R.S.E., *Senior Demonstrator of Anatomy in the University of Edinburgh.*

SIR WILLIAM TURNER recently handed to me for examination the kidneys of a pig, sent to him by Dr Hamilton, Elm House, Hawick, who was under the impression that two pairs of kidneys had been removed from the animal. I made a detailed dissection of the specimen, and, when the mass of adipose tissue in which the organs were embedded was removed, various anatomical structures were displayed, and the true nature of the abnormality revealed. Instead of four kidneys being present, it became evident that there were only two, but that each one was so attenuated across its middle portion as to lead to its accidental severance into two parts during the process of removal from the carcase of the animal, while this peculiar disposition of the organs had been obscured by the accumulated fat.

When the parts of each kidney were restored to their approximately natural positions, the outline of each organ presented very considerable deviation from the normal shape of the pig's kidney.

In this animal, the normal kidney measures about $4\frac{1}{2}$ inches in length and $3\frac{3}{4}$ inches in breadth. On its inferior or mesial border there is a well-marked notch, $\frac{1}{2}$ an inch in length, and on the ventral aspect of this notch the hilum is represented by a triangular depression $\frac{1}{4}$ of an inch in depth by $\frac{3}{4}$ of an inch in length. At this point, the lumen of the ureter is $\frac{1}{8}$th of an inch in diameter.

When the abnormal kidneys were compared with the normal specimen, each of the former was fully 5 inches in length with a maximum breadth of 2 inches. Each presented, on its outer or convex border, a very distinct notch, which was rather deeper in the left kidney. In both kidneys this notch was situated opposite the middle of the hilum. Further, in both of the abnormal organs the hilum was a very pronounced gap affecting the entire thickness of the kidney substance. In

the right kidney this enlarged hilum extended to within an inch of the outer convex border, and in the left kidney it reached rather nearer to the convex border. In both kidneys the hilum measured fully 2 inches in the longitudinal direction.

Fragments of the renal artery and vein were found at each hilum. In each case the wall of the ureter was considerably thickened by infiltrated fat, and within the enlarged hilum the pelvis of each ureter expanded into two wide and capacious channels, which passed into the substance of the kidney at the anterior and posterior ends.

The normal kidney of the pig closely resembles that of the human subject, and the disposition of their ureters is very similar. The abnormal kidneys under consideration present a condition in which the fusion of the original fœtal lobules has to some extent been arrested, but not to such a degree as to lead to the production of two pairs of kidneys.

A CASE OF ABSENCE OF THE RIGHT KIDNEY. By THOMAS DWIGHT, M.D., LL.D., *Parkman Professor of Anatomy at Harvard University.*

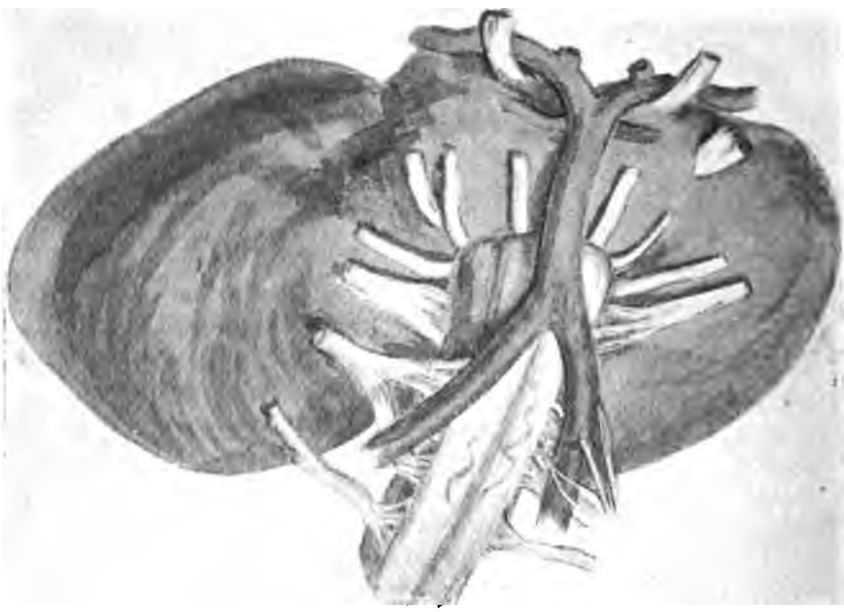
THIS defect was seen, in February 1894, in the body of a young white blind man, aged nineteen, who had died of phthisis. The body was well formed. No anomalies of consequence were observed besides those about to be mentioned. He had lived in an almshouse from his fourth year, being in good health till within a few months of his death. He was blind when admitted, but thought that once he had seen. This was a mistake; for, though the eyes were not in good condition when I examined them, I was able to satisfy myself that it was a case of microphthalmos. The eyeballs were very small, with opaque corneæ, and apparently just alike. The right testicle was extremely small. Indeed, its presence was not considered certain till the scrotum was opened. Unfortunately, it was not measured. It was probably not over 2 cm. in length.

There was no trace whatever of the right kidney, nor of the right renal artery and vein. The left kidney, with a single artery and vein, was in its proper place. It gave the impression of being rather a large kidney. It was 13 cm. long, 7 cm. broad, and 4·3 cm. thick. As both vessels had been injected, its weight could not be ascertained. The ureter was about twice as large as normal. This seems to imply an increased activity. Both supra-renal capsules were present. The vena cava, which was somewhat more to the right than usual, seemed rather small below the left renal vein, but of, at least, normal size above it. The left common iliac vein was abnormally distinct from the artery. The left spermatic artery arose as usual, but ran at first 2 or 3 cm. outward parallel to the renal artery. It then turned round a branch of the spermatic vein, which was double near the end, and ran downwards. The right spermatic vessels had been cut, and could not be traced. The artery, about 1 mm. in

diameter, arose from the right side of the aorta, about opposite the left renal artery, but was soon lost. Followed from below, the artery and vein ran upwards from the abdominal ring, further out in the flank than usual. The end of the vein could be found neither in the cava nor elsewhere. Nothing resembling the termination of a right ureter could be found at the bladder. When examined from the inside, the right half of the trigonum seemed undeveloped.

NOTE ON A NERVE PIERCING THE WALLS OF AN ARTERY. By JOHN W. OGLE, M.D., F.R.C.P.

MANY years ago, when acting as curator at St George's Hospital, I met with a curious example of an artery, the walls of which were pierced by a nerve. I had a drawing of the specimen made at the time from which the figure is taken, but the preparation itself was not preserved.



After removing the brain, and on turning it over so as to examine the base, I observed that one of the roots of the left hypoglossal nerve pierced the wall of the left vertebral artery, where it was in relation to the medulla oblongata, a little below the pons. It then emerged through the opposite wall, and joined the other root fibres before it reached the nerve trunk. This condition, if not unique, is so rare that it seems worthy of being recorded.

ON THE OSTEOLOGY OF CERTAIN CRANES, RAILS, AND THEIR ALLIES, WITH REMARKS UPON THEIR AFFINITIES. By R. W. SHUFELDT, M.D.

AN opportunity having been afforded me to make a comparative study of the skeletons of numerous birds belonging to the Sub-order PALUDICOLÆ, I propose, in the present brief contribution, to offer some remarks upon the subject of the osteology of that group, and what it seems to suggest to us in regard to the affinities of its members, and the way in which it appears to be related to other avian groups.

As to the osteological material examined during these investigations, I am indebted to the United States National Museum for having placed at my disposal specimens of *Grus americana*, *Grus canadensis*, *Aramus giganteus*, *Ionornis martinica*, *Gallinula galeata*, *Jacana gymnostoma*, *Psophia crepitans*, and the skeletons of a number of Herons, Storks, *Otis*, and their allies near and remote.

To Mr F. E. Beddard, F.R.S., my thanks are due for a perfect skeleton of *Crex crex* and other material; to Mr Philip Laurent of Philadelphia for skeletons of *Rallus longirostris crepitans* and other Rails; to Mr F. A. Lucas for the sternum of *Rallus virginianus* and skeletons of other important forms; to Mr T. S. Palmer, of Berkeley, California, for several skeletons of *Rallus obsoletus*; and finally, my own cabinets have furnished me with much osteological material, as *Porzana carolina* and other *Rallidæ*, Herons, *Limicolæ*, &c.

At the present writing there is by no means a unanimity of opinion among the classifiers of birds on the question of the taxonomy of the Paludicolæ, which, in so far as the United States avifauna is concerned, I take to contain the genera *Grus*, *Aramus*, *Rallus*, *Crex*, *Porzana*, *Ionornis*, *Gallinula*, and *Fulica*. Of what I consider the relationships of these genera to be, I will treat in the sequel.

In the year 1813, the Academy of Sciences of Berlin, in its

Abhandlungen (pp. 237–259), published a scheme of bird classification proposed by Blasius Merrem, entitled a *Tentamen Systematis naturalis Avium*. That gifted writer distinguished his fourth group of birds as "Aves palustres," and thus divided it:—

4. Aves palustres.
   A. Rusticolæ: *a.* Phalarides—*Rallus*, *Fulica*, *Parra*; *b.* Limosugæ—*Numenius*, *Scolopax*, *Tringa*, *Charadrius*, *Recurvirostra*.
   B. Grallæ: *a.* Erodii—*Ardeæ* unque intermedio serrato, *Cancroma*; *b.* Pelargi—*Ciconia*, *Mycteria*, *Tantali* quidam, *Scopus*, *Platalea*; *c.* Gerani—Ardeæ cristatæ *Grues*, *Psophia*.
   C. *Otis*.

For the time it was given, this classification is by no means altogether lacking in merit, and there are taxonomers of the present day who may with profit still contemplate it.

Fourteen years later L'Herminier in his "Recherches sur l'appareil sternal des Oiseaux," published in the *Actes* of the Linnæan Society of Paris (vi. pp. 3–93), showed upon osteological grounds that the *Rallidæ* and the true Cranes (*Grus*) were affined, and neither family were especially related to the Herons (*Ardeidæ*), and so should be separated from them.

Passing the classifications of many of the early writers, always more or less conflicting in their views, we come to the famous scheme of Professor Huxley, so frequently quoted in my taxonomical papers. (*P. Z. S.*, 1867.)

In his Order III. (CARINATÆ, Merrem), Group 2 (Geranomorphæ), Huxley arrays two families thus:—

Family 1. GRUIDÆ.
  Intermediate forms: *Psophia*, *Rhinochetus*.
Family 2. RALLIDÆ.
  Intermediate forms: *Otis*, *Cariama*.

And remarks thereon that he considered the Cranes and the Rails as constituting the typical forms of the group. The Herons he places in a distinct suborder, the Desmognathæ, in a

Group Pelargomorphæ, containing the Ardeidæ, the Ciconiidæ, and the Tantalidæ.

In the curious and unique classification of Garrod (*P. Z. S.*, 1874, p. 116), we find his Sub-class Homalogonatæ divided into numerous orders, the first of which is the *Galliformes*. This latter he divides into "Cohorts" α, β, γ, &c.—Cohort β being the Gallinaceæ, and it is thus divided:—

Family 1. Palamedeidæ.
„ 2. Gallinæ.
„ 3. Rallidæ.
„ 4. Otidæ.
Sub-family 1. Otidinæ.
„ 2. Phœnicopterinæ.
Family 5. Musophagidæ.
„ 6. Cuculidæ.
Sub-family 1. Centropodinæ.
2. Cuculinæ.

It is not surprising, in a classification of this nature, to find the Herons in another order placed between the *Cathartidæ* and the *Steganopodes*, while the *Gruidæ* are consigned to still a different order, from the Rails for example, and placed between the Plovers and Gulls (among the Limicolæ),—the only other Cohort in the same order being the Columbæ.

The XVIth Order of Doctor Sclater's scheme is the *Fulicariæ*, which is created to contain (*a*) the *Rallidæ* and (*b*) the *Heliornithidæ*. In the XVIIth he places the (*a*) *Aramidæ*; (*b*) *Eurypygidæ*; (*c*) *Gruidæ*; (*d*) *Psophiidæ*; (*e*) *Cariamidæ*; and (*f*) the *Otidæ*. The *Parridæ* he places in Order XVIII.—the LIMICOLÆ.

Professor Newton, ever cautious and far-seeing in everything he has done in ornithology, although the present writer does not always coincide with him in all his views,—as in the present instance,—places in the HERODIONES the *Ardeæ*, the *Ciconiæ*, and the *Plataleæ*.

Fulicariæ and *Grues*, the latter made to include the *Gruidæ*, *Psophiidæ*, *Aramidæ*, *Eurypyga* and *Rhinochetus*, make up the *Grallæ*.

Doctor Reichenow, who in 1882 gave us his *Die Vögel der Zoologischen Gärden*, divides the Class Aves into "Series."

Series III. is the GRALLATORES, being split up into orders, sub-orders, families, &c., and I extract the following from it:—

Suborder B. ARVICOLÆ.

Family 19. Otididæ.
„ 20. Gruidæ.

Suborder C. CALAMOCOLÆ.

Family 21. Rallidæ.
Subfamily A. Rallinæ.
„ B. Gallinulinæ.
„ C. Parrinæ.
Family 22. Eurypygidæ.

Suborder D. DESERTICOLÆ.

Family 23. Thinocoridæ.
„ 24. Turnicidæ.
„ 25. Pteroclidæ.

Order VII. GRESSORES.

Family 26. Ibidæ.
„ 27. Ciconidæ.
„ 28. Phœnicopteridæ.
„ 29. Scopidæ.
„ 30. Balænicipidæ.
„ 31. Ardeidæ.

In 1884 appeared the second edition of Dr Cones's *Key* to North American Birds, and in it we meet with the following scheme:—

Order.	*Suborder.*	*Families.*	*Subfamilies.*
ALECTORIDES.	Gruiformes.	Gruidæ. Aramidæ.	
	Ralliformes.	Parridæ.	
		Rallidæ.	Rallinæ. Gallinulinæ. Fulicinæ.

Dr Leonard Stejneger in 1885 proposed a classification in that now well-known work, *The Standard Natural History*. In it he places the *Jacanidæ* in his Superfamily SCOLOPACOIDÆ

of the Order GRALLÆ, and the *Gruidæ*, *Aramidæ*, and the *Rallidæ* in another superfamily—the GRUIOIDEÆ, of the same order. The Storks and Herons are removed to another order—the HERODII.

In the first edition of the *Check-List of the American Ornithologists' Union*, the following scheme is given (1886):—

Order.	*Suborders.*	*Families.*	*Subfamilies.*	*Genera.*
PALUDICOLÆ.	Grues.	Gruidæ.		*Grus* (3 sp.)
	Ralli.	Aramidæ.		*Aramus* (1 sp.)
				Rallus (6 sp.)
				Porzana (5 sp.)
				Crex (1 sp.)
			Gallinulinæ.	*Ionornis* (1 sp.)
				Gallinula (1 sp.)
			Fulicinæ.	*Fulica* (2 sp.)

Here the *Jacanidæ* are placed as the last family of the LIMICOLÆ.

Fürbringer places the *Parridæ* in a Gens PARRÆ of a Suborder Charadriiformes, which belongs to his Order CHARADRIORNITHES. Between this order and the Order ALECTORORNITHES we find inserted two intermediate suborders, thus:—

Suborder.	*Gens.*	*Families.*
Gruiformes.	Eurypygæ.	Eurypygidæ.
		Rhinochetidæ.
		Aptornithidæ.
	Grues.	Gruidæ.
		Psophiidæ.
		Cariamidæ.
Ralliformes.	Fulicariæ.	Heliornithidæ.
		Rallidæ.
	Hemipodii.	Mesitidæ.
		Hemipodiidæ.

In his exceedingly useful *Review of Recent Attempts to Classify Birds*, my friend Dr Sharpe also places the PARRÆ

in an Order Charadriiformes (Order XVIII.), while the GRUES and ARAMI are in an Order Gruiformes, along with the Rhinochetides, Mesitides, Eurypygæ, Psophiæ, and Dicholophi (Order XIX.).

Doctor Hans Gadow, who has accomplished so much in the morphology of birds, has given us at least two schemes of classification for the class. One of these appears in Bronn's *Thierreich* (AVES), and the earlier one in the *P Z. S.* (1892, p. 229), being a paper "On the Classification of Birds." In this latter he places the *Parridæ* among the LIMICOLÆ, and divides his GRUIFORMES into the Eurypygæ, Ralli, Grues, Dicholophi, and Otides.

There are a number of others we might quote, but enough has been presented for my purpose: that is, to show that a great variance of opinion still exists among the best authorities on the subject, but that the *tendency* seems to be to keep the *Gruidæ*, the *Rallidæ*, and the *Aramidæ* associated more or less closely together, and well-removed from the Herons and Storks and Ibises; while the *Parridæ* are placed among the limicoline forms, more or less near the Plovers.

During my studies of the Paludicolæ, I wrote out a very detailed account of their osteology, making many comparisons, and illustrating my work with a good many figures. These labours it is my purpose to use in another connection, offering here for the present only a few selected synoptical tables of characters, a general abstract, and a few figures.

Several years ago the writer published a full description of the "Osteology of *Porzana carolina*" in the *Journal of Comparative Medicine and Surgery* (July 1888), and the following is a brief recapitulation of the skeletal characters of that species, extracted therefrom.

Synoptical Table of the Osteological Characters of Porzana carolina.

1. External narial apertures on sides of superior osseous mandible very large.
2. Lacrymal bones free, and possessed of delicate descending processes.

3. Pars plana ample, quadrilateral in outline, supero-external angle fusing with under side of frontal bone.
4. Vacuity in inter-orbital septum very large.
5. Mastoidal head and mandibular foot of quadrate each have two articular prominences.
6. Vomer free, deeply cleft behind for the rostrum, minutely tricornuate at its anterior apex.
7. Maxillo-palatines concavo-convex, long, and separated from each other in the median line.
8. Postero-external angles of palatines completely rounded off. Their maxillary processes long and very slender, being widely apart and nearly parallel to each other.
9. Pterygoids rather short, and lamelliform.
10. Mandibular angles of mandible truncate below, but developing recurved processes immediately behind the articular cups.
11. Occipital condyle small, foramen magnum relatively very large.
12. Type of skull holorhinal and schizognathous.
13. The furcula U-shaped, deep and without hypocleidium (negative character). Scapulæ long and narrow, coracoids rather short in comparison.
14. Sternum with lofty costal processes; notched anterior border, rudimentary manubrium, xiphoidal extremity profoundly cleft once on either side; carina deep, extending entire length of sternal body, which latter, seen from above, is long and narrow.
15. Length of pelvis far exceeds its greatest width. Supero-internal margins of preacetabular portions of ilia concave, exposing on lateral view the fused neural spines of sacral vertebræ. Propubis present. Ischiac foramen sub-circular. Postacetabular portion of ilium develops an overhanging ledge of bone on lateral aspect. Postpubis separated from ischium for its entire length after passing the obturator foramen. Ilio-ischiac notch present on posterior margin of bone. Ilia extend well beyond the sacrum behind.
16. Pollex digit of manus supports a claw.

FIG. 1.—Right lateral aspect of skull and mandible (detached) of *Aramus giganteus*. Natural size.

FIG. 2.—Right lateral aspect of skull and mandible of *Rallus longirostris crepitans*. Natural size.

Both figures from photographs made by the author direct from the specimen.

17. Cnemial crest of *tibio-tarsus* rises above articular summit of the shaft. Bony bridge for extensor tendons at distal end of the bone thrown directly across the groove. External condyle below it, much larger than the internal one on anterior aspect. Hypotarsus of *tarso-metatarsus* grooved only; mid-trochlea the lowest, inner one the highest, on the shaft, and is turned to the rear. Arrangement of phalanges of podal digits normal (2, 3, 4, 5); the joints long and slender, but on the whole harmoniously proportioned as to lengths and calibres.

The osteological characters that distinguish *Crex* from *Porzana* are but of generic value, and the two forms are markedly alike in these particulars. So much is this the case, and so gradual is the change from *Crex* through *Porzana* to typical *Rallus*, that the distinction between "Land" and "Water-Rails" still entertained by some authorities practically breaks down.

My work in MSS. gives a full detailed comparative description of the skeleton of *Crex*, as well as that of *Rallus*, *Ionornis*, and *Fulica*, but those descriptions are too long to insert in this place. Many of the characters found are of great interest and no little importance.

In a great many particulars *Porzana*, *Crex*, *Rallus*, *Ionornis*, *Fulica*, and *Gallinula* agree in their osteology, but there are nevertheless a number of very significant differences. *Crex* stands between *Rallus* and *Porzana*, rather than between *Porzana* and the *Gallinulinæ*, to which latter place it has been incorrectly assigned by some authorities.

My very careful comparisons of the skeletons of *Aramus* and *Grus* have interested me in no small degree, but they have forced me to the adoption of a very different opinion from the one held by Garrod, and published by him in the *P. Z. S.* in 1876 (pp. 275–7). I refer to his paper, "On the Anatomy of *Aramus scolopaceus*," wherein he remarked of the bird, "The sternum is completely Gruine, as are the other parts of its skeleton" (p. 275); by which he meant, I presume, in a general way, for if he meant anything else by the word "completely," what he said will by no means strictly apply to *Grus americanus*, as will be

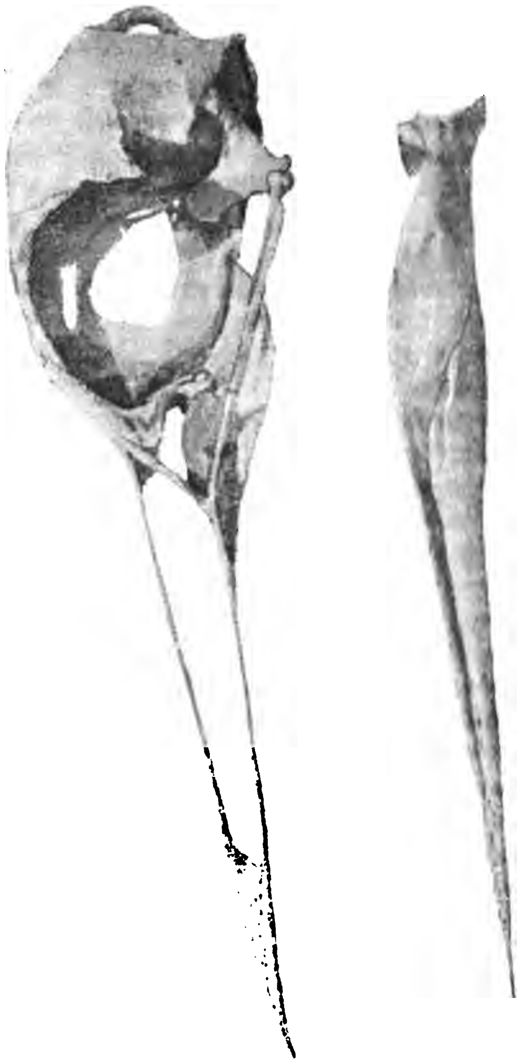


FIG. 3.—Left lateral view of skull and mandible (detached) of *Grus canadensis*. Natural size.

From a photograph made by the author direct from the specimen.

seen from the synopsis of osteological characters of *Rallus*, *Aramus*, and *Grus americanus* given in the following table:—

TABLE.

Rallus longirostris.	*Aramus giganteus.*	*Grus americana.*
1. Supra-orbital border distinctly marked for nasal glands.	1. Supra-orbital border very faintly trimmed by nasal glands.	1. Supra-orbital border well marked behind for nasal glands.
2. Vacuity in inter-orbital septum very large.	2. Vacuity in inter-orbital septum much smaller.	2. Vacuity in this septum intermediate in size, with another elongated one above it.
3. Maxillo - palatines elongated, swollen, may be in contact in middle line.	3. Maxillo - palatines elongated, much less swollen; never in contact.	3. Maxillo - palatines large, leaf-like, never in contact.
4. Vomer pointed, spreading slightly.	4. Vomer pointed, transversely compressed.	4. Vomer pointed, decidedly spread horizontally.
5. Præpalatines extremely slender.	5. Præpalatines broad.	5. Præpalatines broad.
6. Pterygoids short, straight rods, nearly uniform in calibre.	6. Pterygoids short; *posteriorly* dilated; twisted on themselves.	6. Pterygoids short; sub-dilated *anteriorly;* borders more or less sharp.
7. Twenty-one vertebræ between skull and pelvis, all of which are freely articulated.	7. Twenty-three vertebræ between skull and pelvis; 18th, 19th, and 20th fused together.	7. Twenty-four vertebræ between skull and pelvis; 20th, 21st, and 22nd are fused together.
8. Fourteenth and fifteenth vertebræ have free ribs, which do not have hæmapophyses connecting with the sternum.	8. Seventeenth vertebra has the first and only pair of free ribs; they do not connect with the sternum.	8. Eighteenth vertebra has the first and only pair of free ribs that do not connect with the sternum.
9. One pair of pelvic ribs.	9. One pair of pelvic ribs.	9. Three pairs of pelvic ribs.
10. Ilio-neural canals of pelvis are open behind.	10. Ilio-neural canals of pelvis are completely closed up behind.	10. Ilio-neural canals as in *Aramus.*
11. In the pelvis, the externo-lateral iliac ledge of bone is entirely posterior to the ischiac foramen, and is well developed.	11. The same as in *Rallus*, but not so conspicuously developed.	11. *Two* such bony ledges are developed; one overhangs the antitrochanter and ischiac foramen, and the other, small and far back, overarches the posterior part of the ischium.
12. Twelve vertebræ enter into the formation of the pelvic "sacrum."	12. Fourteen vertebræ enter into the formation of the pelvic "sacrum."	12. Seventeen vertebræ enter into the formation of the pelvic "sacrum."

Rallus longirostris.	*Aramus giganteus.*	*Grus americana.*
13. *Sternum* long and very narrow; two-notched; xiphoidal processes longer than mid-posterior projection of the body of the bone; carina deep, extends the entire length of sternal body; carinal angle angulated; five facets on either costal border; coracoidal grooves merge into one; the bone is non-pneumatic. In the *shoulder-girdle* the *os furcula* is of the U-pattern, very slender and deep. It articulates with the scapula on either side. It may have an epicleidium developed. Scapula very long and narrow; is curved throughout and gradually brought to a point posteriorly. A *coracoid* shows the foraminal perforation in its scapular wing or process. All the bones of the arch are non-pneumatic.	13. *Sternum* oblong, long and narrow; unnotched; middle of xiphoidal border slightly emarginated; carina not very deep, extends the entire length of sternal body; carinal angle rounded; six facets on either border; coracoidal grooves slightly decussate; the bone is pneumatic. In the *shoulder-girdle* the *os furcula* is of the perfect U-pattern; clavicular limbs broad and flattened, the symphysis has its plane surface facing to the front, the reverse being the case for the rami. The bone articulates with the *scapula*. The latter is relatively shorter and broader than in *Rallus*. Large scapular wing of *coracoid* pierced by foramen; the bone is short and stout. The arch is largely pneumatic.	13. *Sternum* oblong, long and narrow; xiphoidal margin perpendicular to the axis of the sternal body, and ragged; carina rather deep, extends nearly the entire length of sternum; carinal angle fused with furcula; seven facets on either costal border; coracoidal grooves separated in middle line; bone highly pneumatic; trachea enters carina and bony box in front of it to form one or more loops or coils therein. In the *shoulder-girdle* the *os furcula* is a deep open V-type. It anchyloses with the sternum below, and does not articulate with scapula above. *Coracoids* and *scapulæ* agree essentially with *Aramus* in other particulars. The bones of the arch completely pneumatic.
14. Humerus non-pneumatic; characters of pectoral limb agree with *Crex*, *Porzana*, &c.	14. Humerus pneumatic; characters of pectoral limb agree with *Grus*, &c.	14. Humerus pneumatic; characters of pectoral limb essentially as in *Aramus*.
15. Skeleton of pelvic limb typically ralline; hypotarsus of tarsometatarsus faintly grooved. *Pes* typically ralline; joints of phalanges slender and long.	15. Skeleton of pelvic limb largely gruine; hypotarsus deeply grooved. *Pes* essentially ralline; joints of phalanges slender and long.	15. Skeleton of pelvic limb typically gruine; hypotarsus once-perforated and also faintly grooved. *Pes* typically gruine; joints of phalanges short and stout.

Taxonomy of the North American Paludicoline Birds.

So far as this suborder,—the Paludicolæ,—of the United States is concerned, it is primarily divided into two main stems. The first of these represented by the Cranes and Courlans; while the second contains all the Rails proper, or such generic groups as *Rallus*, *Crex*, *Porzana*, *Ionornis*, *Gallinula*, and *Fulica*.

Structurally, the Courlans possess a greater number of gruine characters than they do ralline ones, and those characters are of equal importance and weight. But their gruine characters are by no means always typical, and the differences seen are frequently of a degree that distinguish families among birds rather than genera. This being true, the fact settles the position of the Courlans in the system as a family,—the *Aramidæ* of the Crane-group. The species which has been osteologically described here,—*Aramus giganteus*,—is the only representative known to our avifauna, and it is a most perfect link connecting the Cranes with the typical *Rallidæ*.

The Cranes must then constitute a family of themselves, and the *Gruidæ* has long been created to contain them. But the osteological and other morphological characters held in common by the *Gruidæ* and the *Aramidæ* are of a rank, when we come to compare them with the corresponding ones in the *Rallidæ*, which proclaim them to be higher than those commonly employed to define family lines, and yet not of a rank entitling them to subordinal distinction. To express this relationship, a Superfamily GRUIOIDEA may be made to contain all the true *Gruidæ*, the *Aramidæ*, — and perhaps the *Psophidæ*, — from another quarter of the world. Another group to contain all the true Rails may be created, and designated as the Superfamily RALLIOIDEA. A scheme as follows would show these divisions as expressed for the forms we have had under consideration.

Suborder.	*Superfamilies.*	*Families.*	*Genera.*
PALUDICOLÆ.	GRUIOIDEA.	Gruidæ.	Grus.
		Aramidæ.	Aramus.
	RALLIOIDEA.	Rallidæ.	Rallus.
			Crex.
			Porzana.
			Ionornis.
			Gallinula.
			Fulica.

The bird-forms connecting the Paludicolæ with other avian groups are often not far to seek It is plain that we have in the *Jacanidæ* a small group of birds that unmistakably link the present suborder with the Limicolæ, through certain species

in the plover-sandpiper line. Through *Podica* and *Heliornithes* it is equally clear that they lead in this direction towards the Pygopodes, and such existing ancestral types as *Chiornis* probably connect them with the Longipennes. Less remote than this latter affinity, however, they are probably connected by various links with the Herodiones, as through *Rhinochœtus* and *Eurypyga*. By some it has also been claimed that the Paludicolæ may also have accipitrine kinships through a line in which would occur such forms as the Seriema and the Secretary Bird (*Serpentarius*).

Professor Fürbringer believes that the *Apteryges* are far more closely related to the *Rallidæ* than has heretofore been realised; and if this prove to be true, another linking line for the Paludicolæ is opened up to the Struthious types,—with all the *Gallinæ* likewise only a little more remotely related.

FIFTH ANNUAL REPORT OF THE COMMITTEE OF COLLECTIVE INVESTIGATION OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND FOR THE YEAR 1893–94.[1] Reported by ARTHUR THOMSON, M.A., M.B., *Professor of Human Anatomy, University of Oxford.*

THE following questions were issued by the Committee of Collective Investigation early in October 1893:—

1. State in each subject examined, particularly noting the sex, whether the following muscles are present or absent on one or other side, or both—(*a*) pyramidalis abdominis; (*b*) palmaris longus; (*c*) plantaris.
2. Note any variations in the form and connections of the V lumbar and I sacral vertebræ, and mention the spinal nerve which (1) forms the superior limit of the lumbar plexus; (2) separates the lumbar from the sacra plexus (n. furcalis); (3) limits inferiorly the great sciatic (or internal popliteal) nerve.

   NOTE.—The object of the above questions is to determine—(*a*) the frequency of the tendency which exists towards the assumption by the V lumbar vertebra of sacral characters and the assumption by the I sacral vertebra of lumbar characters, with a view to ascertain which tendency is the stronger of the two; (*b*) whether there is any co-relation in the variations in the position of the limb and limb plexus.

3. To note the point in the spinal canal to which the spinal cord descends in different subjects and different sexes.
4. To note the level of the bifurcation of the common iliac arteries.

   (The classification of the returns will be greatly facilitated by the use of sketches or rough diagrams, and also by more precise information as to the manner in which the observations recorded have been made, whether they refer to the condition noted *on one side only* or *both*. In all cases record the sex of the subject.)

[1] The Fourth Annual Report appeared in the *Journal of Anatomy and Physiology*, vol. xxviii., October 1893.

Replies have been received from nineteen of the thirty-nine institutions to which notices were sent in the subjoined list. The schools which have contributed to the present inquiry are distinguished by an asterisk. The Secretary reports that several teachers have written to him expressing their regret that, from unavoidable circumstances, they have this year been unable to support the scheme.

*St Bartholomew's Hospital, London.
*Charing Cross Hospital, London.
St George's Hospital, London.
Guy's Hospital, London.
King's College, London.
London Hospital, London.
*St Mary's Hospital, London.
Middlesex Hospital, London.
*St Thomas' Hospital, London.
*University College, London.
*Westminster Hospital, London.
*London School of Medicine for Women.
Cook's School of Anatomy.
*University of Oxford.
*University of Cambridge.
*Queen's College, Birmingham.
Bristol Medical School.
*School of Medicine, Yorkshire College, Leeds.
School of Medicine, University College, Liverpool.
*The Owens College, Manchester.
Medical School, Firth College, Sheffield.
*University of Durham School of Medicine, Newcastle-on-Tyne.
*University of Edinburgh.
School of Medicine, Royal College of Surgeons, Edinburgh.
School of Medicine, Minto House, Edinburgh.
*University College, Dundee.
School of Medicine for Women, Edinburgh.
University of Aberdeen.
*University of Glasgow.
Anderson College, Glasgow.
St Mungo's College, Glasgow.
Western Medical School, Glasgow.
*School of Physic, Trinity College, Dublin.
Carmichael School of Medicine, Dublin.
*Catholic University School of Medicine, Dublin.
Royal College of Surgeons, Ireland.
*Queen's College, Belfast.
Queen's College, Cork.
Queen's College, Galway.

REPORT.

QUESTION I.

State in each subject examined, particularly noting the sex, whether the following muscles are present or absent on one or other side, or both—(*a*) pyramidalis abdominis; (*b*) palmaris longus; (*c*) plantaris.

The following gentlemen have sent in replies:—

Messrs John Tennant, Queen's College, Belfast; P. Macleod Yearsley, Westminster Hospital; Wm. Shackleton, Trinity College, Dublin; A. A. Baxter Tyrie, Yorkshire College, Leeds; P. J. Fagan, Catholic University Medical School, Dublin; F. G. Parsons, St Thomas' Hospital; R. C. Baily, St Bartholomew's Hospital; A. A. Warden, University of Glasgow; H. Muir Evans, University College, London; H. Coates, The Owens College, Manchester; A. Thomson, The University of Oxford; Charles Gibb, Charing Cross Hospital; J. B. Yeoman, University of Edinburgh; R. Howden, University of Durham College of Medicine; F. A. Michôd, St Mary's Hospital; W. H. Whitehouse, Mason College, Birmingham; E. Barclay Smith, University of Cambridge; and Mrs Flemming and Miss Piercy, of the London School of Medicine for Women.

The results are shown in Table I. Only those cases have been recorded where both sides of the subject have been examined. The total number of male and female subjects examined is given under each muscle, but it will be observed that these totals do not correspond to the sum of the figures above. This is due to the fact that where the muscle has been present on one side only, its *absence* on the opposite side has been duly recorded; it has therefore been necessary to deduct these figures from the total in order to give the correct number of *subjects* examined.

The results speak for themselves.

Absence of the *pyramidalis* and *plantaris* on both sides appears to be more frequent in the *female* than in the *male*, whilst in the case of the *palmaris longus* absence on both sides is not quite so frequent in the *female* as in the *male*.

In regard to the absence of these muscles on one or other side, the *palmaris longus* and *plantaris* appear to be absent more frequently on the left than on the right side, while in the case of the *pyramidalis abdominis* the left half of the muscle seems to be the portion which more frequently persists. These conclusions apply equally to males and females. The following notes are gleaned from the individual returns.

Professor Howden writes as follows:—

In the two males where both pyramidales were absent, the palmaris and plantaris were present on both sides.

Of the two males in which the palmaris was absent on both sides, one showed the pyramidalis and plantaris present on both sides, while in the other the pyramidalis and plantaris were absent on the right side.

In the female where the palmaris was absent on left side, the plantaris was wanting on the same side, while that of the right side was very small.

In the female which showed the absence of the right pyramidalis, the palmaris and plantaris were present on both sides.

In the male where the plantaris was absent on the left side, the presence or absence of the palmaris was unfortunately overlooked, while the pyramidalis was present on both sides.

TABLE I.

	PYRAMIDALIS ABDOMINIS.		PALMARIS LONGUS.		PLANTARIS.	
	Male Subjects.	Female Subjects.	Male Subjects.	Female Subjects.	Male Subjects.	Female Subjects.
Both muscles present, . .	161 or 74·5 pr. ct.	109 or 73·1 pr. ct.	144 or 81·8 pr. ct.	107 or 82·9 pr. ct.	173 or 90·1 pr. ct.	129 or 86 pr. ct.
,, ,, absent, . .	37 ,, 17·1 ,,	30 ,, 20·1 ,,	19 ,, 10·8 ,,	11 ,, 8·6 ,,	9 ,, 4·6 ,,	12 ,, 8 ,,
Right muscle present, . .	7 ,, 3·2 ,,	2 ,, 1·3 ,,	8 ,, 4·5 ,,	8 ,, 6·2 ,,	7 ,, 3·6 ,,	7 ,, 4·6 ,,
,, ,, absent, . .	11 ,, 5·1 ,,	8 ,, 5·3 ,,	5 ,, 2·8 ,,	3 ,, 2·3 ,,	3 ,, 1·5 ,,	2 ,, 1·3 ,,
Left muscle present, . .	11 ,, 5·1 ,,	8 ,, 5·3 ,,	5 ,, 2·8 ,,	3 ,, 2·3 ,,	3 ,, 1·5 ,,	2 ,, 1·3 ,,
,, ,, absent, . .	7 ,, 3·2 ,,	2 ,, 1·3 ,,	8 ,, 4·5 ,,	8 ,, 6·2 ,,	7 ,, 3·6 ,,	7 ,, 4·6 ,,
Total number of subjects examined,[1] . .	216 ...	149 ...	176 ...	129 ...	192 ...	150 ...

[1] See note in text.

Mr Coates of the Owens College notes that in six cases (5 ♂ and 1 ♀) all three muscles were represented on both sides; in no case were they all absent on both sides.

Dr Barclay Smith, of Cambridge University, furnishes the following details in regard to the pyramidalis muscle.

"In only fifteen cases, however (30 per cent.), where two muscles were present, were the muscle slips of the two sides symmetrically disposed, while in twenty cases (40 per cent.) they were asymmetrical. The muscle was much more frequently absent, and tended to be much less symmetrically disposed in the female than in the male.

	Male.	Female.	Total.
Symmetrical, .	14 (33·3 per cent.)	1 (12·5 per cent.)	15 (30 per cent.)
Asymmetrical, .	18 (42·8 per cent.)	2 (25 per cent.)	20 (40 per cent.)
Right larger than left,	12 (28·6 per cent.)	1 (12·5 per cent.)	13 (26 per cent.)
Left larger than right,	6 (14·3 per cent.)	1 (12·5 per cent.)	7 (14 per cent.)

One remarkable feature evidenced from the tables is, that in the eight cases where the muscle was found on one side only this was invariably on the left side,—in no one instance was a single muscle found on the right side; on the other hand, when the muscle was found on both sides, but asymmetrically disposed, it was more frequently (about 2 to 1) found to be larger on the right side than on the left side.

The muscle in most cases arose by muscle fibres from the ant. aspect of the pubis and the anterior pubic ligaments, but the extent to which it was attached to the pubis exhibited considerable variation, sometimes being attached to its upper edge, in other cases extending to a much lower level. In a few cases the origin and the lower part of the muscle consisted of glistening tendinous fibres.

As a rule, the two muscles were separated by a very strong septum, the continuation of the linea alba; but in some cases this distinction was not so marked, especially at their origin, where the two muscles were occasionally inseparably blended; also, in some few cases, the muscle bellies above the symphysis pubis were united by crossing muscle fibres.

On the other hand, the two muscles were sometimes separated by a triangular interval. In one or two instances this triangular interval was median, and involved an equal deficiency in the two muscles, but in most cases it was lateral, the inner edge of one muscle corresponding to the median line, while the inner edge of the other muscle was oblique, bounding with the median line a triangular interval which had its base at the pubis.

This deficiency occurred more frequently on the left than on the right side; and in one case where the left muscle only was present, it also exhibited a triangular deficiency towards the median line.

The upper limits of the muscle were in some cases rather difficult to define accurately, the fibres blending insensibly with the connective tissue of the linea alba.

Careful measurements of the muscle were made in each case with

calipers, the vertical length being taken from the lowest point of attachment to the pubis to the point where it was lost in the linea alba,—the breadth being taken at its widest part, either at or close to its origin.

	Right.	Left.
Average length when present,	67·16 mm.	64 mm.
„ breadth „	20·34 mm.	18·8 mm.

The maximum length noted was 95 mm., which occurred in two cases, in both instances the two muscles being of the same length.

The minimum length noted was 40 mm., which occurred once in a symmetrically disposed muscle, and once in a muscle present on the left side only.

The development of the muscle fibres exhibited considerable variation, the actual measurements not giving a fair criterion of the muscle, as in some cases the muscle belly was thick and well developed, in others composed of a thin sheet of fibres, which were occasionally more or less largly admixed with fat. In one or two cases the fibres were not so obliquely disposed, and were not so convergent on one side as on the other.

In no case was duplication of the muscle noted."

Dr A. A. Warden, of the Glasgow University, also furnishes some details in regard to the development of this muscle. In twenty-one male and nine female subjects it varied between 2 and 3 inches in length, and ½ inch to 1 inch in breadth at the pubis. In two female subjects it measured as much as 5¼ and 4 inches in length, the left portion of the muscle being the larger by 2¼ inches in one case and 1 inch in the other.

Mr P. Macleod Yearsley, F.R.C.S., of Westminster Hospital, records three cases in which the muscle was 4 inches long on both sides, two in which it was 5 inches long on both sides, one in which it measured 5¼ on the two sides, and an instance in a male in which it measured 6 inches on both sides.

In regard to the palmaris longus, Dr Barclay Smith furnishes the following details:—

"The size of the muscle belly varied between 77·5 mm. and 163 mm., the average length being 117 mm.

In five cases the muscle belly was longer than the tendon of insertion, but in one of these cases there was a long tendon of origin above the muscle belly. (The length of the tendon is taken from the point of ending of the muscle belly to the point where it spreads out to become continuous with the palmar fascia.)

Origin.—The muscle took origin from the internal epicondyle in common with the general flexor tendon, and by muscle fibres from the strong fascia covering it and the septa separating it from the adjoining muscles. In some cases tendinous fibres, distinct from the general flexor tendon, could be traced to the epicondyle, in others the attachment to the epicondyle was by means of muscle fibres, and in others the origin was partly tendinous and partly muscular. In one

case the origin was in common with that of the flexor carpi radialis, and distinct from that of the other flexors. In two cases there was a long and distinct tendon of origin preceding the muscle belly.

Disposition of Muscle Fibres.—The relation of the muscle fibres to the tendon of insertion exhibited considerable variation. In some cases a fusiform muscle merged gradually into tendon, but in most cases the muscle fibres were attached obliquely to the tendon, which was situated, as a rule, to the ulnar side of the muscle, rarely to the radial side. The tendon more frequently commenced on the deep than on the superficial aspect of the muscle. In one case the muscle was rhomboidal, the fibres being disposed obliquely between a tendon of origin on the radial side and a tendon of insertion on the ulnar side. In three cases the muscle fibres were attached bipenniformly to the tendon.

Insertion.—No abnormalities were met with, the fibres of the tendon passing superficially to the annular ligament, and spreading out to become continuous with the palmar fascia, but in one case there was a considerable blending with the annular ligament, and the two were inseparable.

Relation to other Muscles.—The muscle was usually in direct relation with the flexor carpi radialis on its outer side, and with the flexor sublimis digitorum beneath and to its inner side, separating it from the flexor carpi ulnaris. The palmaris was separated from these two muscles by strong facial septa, which, with the fascia lata covering its superficial surface, formed a complete investing sheath to which, in the majority of cases, its muscular fibres were attached. The septum separating it from the flexor carpi radialis was, as a rule, much stronger and better marked than that separating it from the flexor sublimis digitorum; in some cases, in fact, the latter septum when traced upwards became excessively thin and disappeared, the fibres of the palmaris becoming inseparable from those of the flexor sublimis.

The fascial sheath, when traced upwards, became continuous with the common flexor tendon, and was always better marked when the muscular fibres were not directly attached to bone.

In one case the muscle came into direct relation with, and was separated by a septum from, the flexor carpi ulnaris, the flexor sublimis not coming to the surface between the two."

Mr Yearsley describes a case in which the palmaris longus arose from the common flexor tendon by a long narrow tendon about the middle of the forearm. This entered a small muscular belly about 1 inch in length, and from this passed a narrow tendon of insertion to the palmar fascia.

Mr Shackleton, of Trinity College, Dublin, mentions two instances in which the muscle was double, one in a right, the other in a left arm; and records two cases, both occurring in left limbs, in which the muscle was inserted into the pisiform bone.

Mr Chas. Gibb, of Charing Cross Hospital, observed the insertion of the muscle into the abductor minimi digiti, with which it became blended; and Dr Baxter Tyrie, of the Yorkshire College, Leeds, describes the muscle in the right arm of a male subject as possessing

a fleshy origin, a central tendon, and a fleshy insertion continuous with the abductor pollicis.

Dr A. A. Warden, of Glasgow, enumerates the following varieties of muscle which he met with in the course of his observations:—A case in which the muscle was present in two parts in both arms of the same subject. Right arm: the two parts were only distinct below, arising above as one tendon; below, the ulnar part was the larger, and was inserted into the annular ligament and hook of the unciform bone, the radial part passing into the palmar fascia. Left arm: the radial portion consisted of a long thin tendon with a muscular belly 3 inches long; the tendon above this belly was 1″ long, below it 6″ long; the ulnar portion consisted in its lower 6 inches of muscular fibres, the upper 4 inches being entirely tendinous. In another male subject the right muscle was present in two parts, the radial portion being the larger; the radial part arose by muscular fibres above, becoming tendinous below, the ulnar by a long slender tendon from the internal condyle, with a muscular belly 4″ long, terminating below in a short tendon forming the palmar fascia.

The muscle was observed tendinous at its origin and insertion, with an intermediate fleshy belly, varying from 3 to 4¼ inches long in three subjects (1 ♂ and 2 ♀). In another female subject the muscle was tendinous for about 2 inches at its insertion, the rest of the muscle consisting of fleshy fibres.

Mr R. S. Baily, M.S. (London), of St Bartholomew's Hospital, ascertained the presence or absence of the muscle in fifty-two students by causing them to put it in action. The results were as follows:—

In 37	the muscle was		present on both sides.			
„ 9	„	„	absent	„	„	
„ 3	„	„	present on the right side.			
„ 3	„	„	„	„	left	„

In regard to the plantaris muscle the notes are scanty. Dr Warden mentions a case in which the muscle in the right leg of a male was small, and "ended in the tendo Achillis about the middle of the leg." There was also present a muscular belly attached above to the head of the fibula and joining gastrocnemius below, but separate throughout from both soleus and (till insertion) gastrocnemius.

Dr Barclay Smith, of Cambridge, supplies the following notes:—

"Seventeen legs were examined for the condition of this muscle, and only in one case was it found completely absent. This occurred in the left leg in a male subject; the right leg of the same subject, however, was possessed of a well-developed muscle.

The mode of insertion of the tendon of the plantaris seems to be much more variable than the mode of origin.

The origin was in most cases distinct from that of the external head of the gastrocnemius, but in three cases the two arose by a common tendon.

Blending with the tendo Achillis was the usual method of insertion, but in two cases the tendon of the plantaris was implanted on to the

os calcis independently. Very frequently the tendon spread out just above the heel into a fan-shaped expansion. The fibres from this expansion joined variably the tendo Achillis, os calcis, external and internal lateral ligament of the ankle joint, and the fascia. In one case the tendon was traced into the fascia underlying the tendo Achillis, and had no apparent connection either with the bone or with the tendo Achillis."

Question II.

Note any variations in the form and connections of the V lumbar and I sacral vertebræ, and mention the spinal nerve which—

(1) Forms the superior limit of the lumbar plexus.
(2) Separates the lumbar from the sacral plexus (n. furcalis).
(3) Limits inferiorly the great sciatic (or internal popliteal) nerve.

Returns in answer to this question have been received from the following:—

Messrs J. Tennant, Queen's College, Belfast; A. A. Baxter Tyrie, Yorkshire College, Leeds; F. G. Parsons, St Thomas' Hospital; E. P. Paton, St Bartholomew's Hospital; J. B. Yeoman, University of Edinburgh; —— Crawford, University College, Dundee; F. A. H. Michôd, St Mary's Hospital; R. S. Martin, The Owens College, Manchester; and Mrs Percy Flemming and Miss Piercy, of the London School of Medicine for Women.

Unfortunately, owing no doubt to the difficulty of the inquiry, the information supplied has been very fragmentary and incomplete. However, the best use has been made of the material at our disposal, and the subjoined notes present some features of interest.

In regard to the *Form and Connections of the* V *Lumbar and* I *Sacral Vertebræ*, 79 subjects (36 ♂, 27 ♀, and 16 ?) were examined; of that number, 71, or about 90 per cent., were normal, whilst 8, or about 10 per cent., were abnormal. Five of these abnormal cases occur in the report of Dr Baxter Tyrie, of the Yorkshire College, Leeds, who thus describes them:

"Two slight evidences of SI having lumbar characters.

One SI, left side, resembled a lumbar vertebra; right was normal.

One marked sacralisation of [illegible]

One complete sacralisation of L5, and osseous union to the 1st sacral. An interesting observation, which may have some bearing on the matter, was, that in all the examples where the 5th lumbar approached or was completely sacralised, the vertebral column was affected by spondylitis deformans."

Unfortunately, Dr Tyrie does not furnish any information regarding the arrangement of the nerves in these cases.

The remaining three abnormal cases are recorded by Dr John Tennant, of the Queen's College, Belfast, who thus describes them :—

"(1) In the first, a female, the vertebral formula was

$$D_{12} \quad L_6 \quad S? \quad C?$$

Unfortunately, the bones were lost before being completely examined.

(2) In the second case, also a female, the vertebral formula was

$$D_{12} \quad L_6 \quad S_5 \quad C_4$$

In this case the 6th lumbar vertebra had no sacral characters whatever, but there was a well-marked false promontory between it and the V lumbar. The I sacral vertebra had its normal shape and connections, and was chiefly concerned in carrying the ilium ; the auricular surface, however, extended a short distance on to the III sacral segment.

(3) In the third case, a female, the vertebral formula was

$$D_{12} \quad L_5 \quad S_5 \quad C_4$$

The last lumbar vertebra was normal. The I sacral was assuming lumbar characters in the following respects : its body was nearly as wide antero-posteriorly at its lower border as at its upper, and the sacral promontory was below it ; the transverse and articular processes were quite free on the right side, and fused to the one below on the left ; its index was 83·3, that of the last lumbar 88 ; its lateral mass was directed more backwards than usual, and carried a very small part of the auricular surface, and very little of the posterior sacro-iliac ligament."

Each of these three cases was associated with variation in the arrangement of the nerve plexuses, as will be noticed hereafter, the *nervus furcalis* in each instance being formed by the V lumbar nerve.

Concerning the *Nerve which forms the Superior Limit of the Lumbar Plexus*, notes of 73 cases have been obtained. The results are tabulated below.

Nerve forming Upper Limit of Lumbar Plexus.

	Branch from XII Dn uniting with I Ln.	I L nerve only.
Males, . .	31	16
Females, .	14	12
Total both sexes,	45	28

In two cases recorded by Dr Tennant, of Belfast, the communication between the XII dorsal nerve and the I lumbar was present in the right side only in a female, and the left side only in a male.

Nervus furcalis.—The details furnished in regard to this are tabulated below. A total of 110 cases have been examined.

NERVUS FURCALIS.

Lumbar Nerves.

	III	IV	V
Males,	1 (branch to IV)	45	1
Females,	...	22	5
Mixed,	...	36	...
Total,	1	103	6

Under the "first column" in the above table, a case is included in which the sacral portion of the IV lumbar nerve was joined by a branch from the III lumbar nerve. This condition was reported by Mr R. S. Martin, of the Owens College, Manchester.

Of the six cases in which the nervus furcalis is tabulated as derived from the V lumbar nerve, three (1 ♂ and 2 ♀) are recorded by Dr J. B. Yeoman, of the University of Edinburgh, without further comment. The remaining three are described by Dr Tennant, who in each instance found them associated with the abnormal conditions described above in connection with the modifications in form of the last lumbar and first sacral vertebræ.

Lower Limit of Great Sciatic Nerve.

In regard to this point, the information supplied is very scanty. Records of 27 cases only have been furnished. The results have been tabulated below.

NERVE WHICH LIMITS INFERIORLY THE GREAT SCIATIC NERVE.

Sacral Nerves.

	I	II	III
Males,	...	1	15
Females,	1	3	7
Total,	1	4	22

In regard to these, the case in which the nervus bigeminus was the I sacral occurred in Dr Tennant's report, and was associated with the vertebral formula D_{12} L_6 S ? C ? See Dr Tennant's report, case (1), *ante*. In case (2), with a vertebral formula D_{12} L_6 S_5 C_4, the n. bigeminus was the II sacral nerve. In case (3), where the I sacral vertebra assumed lumbar characters on the right side, vertebral formula D_{12} L_5 S_5 C_4, the n. bigeminus was the III sacral nerve.

In addition, Professor Paterson, of Dundee, has furnished an analysis of the mode of origin of the branches of the lumbo-sacral plexus in the subjects which he examined, which is here subjoined.

PROFESSOR PATERSON'S ANALYSIS OF THE MODE OF ORIGIN OF THE BRANCHES OF THE LUMBO-SACRAL PLEXUS.

Origin of Nerves.	Cases.
(*a*) *The hypogastric and ilio-inguinal*, represented by one nerve from L. 1, ...	I. II.
(*b*) *Genito - crural* from 1st L. only in . .	I. II.
" " 2. L., and very slightly from 1st L., in . .	III.
" " 2. L. only in . . .	IV. V. VI.
(*c*) EXT. CUTANEOUS " L. 1. 2 in . . .	I. II. VI.
" " L. 2 in	III.
(*d*) ANT. CRURAL " L. 1. 2. 3. 4 in . . .	I. II.
" " L. 3. 4 in . . .	V.
(*e*) OBTURATOR NERVE " L. 3. 4 in . . .	III. V.
(*f*) ACCESSORY OBTURATOR in two cases only, and springing from L. 3. 4, in	VII. and incomplete VIII.
(*g*) GREAT SCIATIC — *Ext. popliteal* from L. 4. 5. S. 1 in	I. II. III.
(*g*) GREAT SCIATIC — *Int. popliteal* from L. 4. 5. S. 1. 2 in	I. II. IV. VII.
(*g*)*a* " — *Ext. popliteal* from L. 4. 5. S. 1. 2 in	IV. V. VI. VII.
(*g*)*a* " — *Int. popliteal* from L. 4. 5. S. 1. 2. 3 in	V. VI.
" *Int. popliteal* from L. 5. S. 1. 2. 3 in	III.
(*h*) PUDIC N. from S. 2. 3 in	III. IV.
" " S. 3. 4 in	VII.
(*j*) SUPERIOR GLUTEAL from L. 4. 5 in . . .	III. IV.
" " " L. 4. 5. S. 1 in . . .	VII.
(*k*) INFERIOR " " L. 5. S. 1. 2 in . . .	VII.
(*l*) SMALL SCIATIC " L. 4. 5. S. 1. 2 in . .	V. VI.
" " " S. 2. 3 in . . .	VII.
N. TO OBTURATOR INTERNUS from S. 3 in . . .	III.
" QUAD. FEMORIS " L. 4. 5 in . .	V. VI.

QUESTION III.

To note the point in the spinal canal to which the spinal cord descends in different subjects and different sexes.

Returns have been supplied by the following:—

Messrs J. H. Moorhead, Trinity College, Dublin; J. Tennant, Queen's College, Belfast; A. A. Baxter Tyrie, Yorkshire College, Leeds; J. A. Roughan, Catholic University, Dublin; H. J. Waring, St Bartholomew's Hospital; J. J. Urwin, University of Glasgow; J. D. Russell, University College, London; R. H. Wilshaw, The Owens College, Manchester; J. B. Yeoman, University, Edinburgh; H. D. Senior, University of Durham College of Medicine, Newcastle-on-Tyne; J. G. Emanuel, Mason College, Birmingham; and Mrs Percy Flemming and Miss Piercy, of the London School of Medicine for Women.

In all, 198 subjects have been examined; of that number 115 were males and 83 females. The results have been tabulated in Table II.

Table II.—*Level to which the Spinal Cord descends in the Spinal Canal.*

Males.		Level		Females.
1·7 per cent. or 2	1, 1	XII. D.V.		
1·7 per cent. or 2	2	DISC.	1	1 or 1·2 per cent.
54·7 per cent. or 63	4, 1, 5, 15, 2, 17, 19	I. L.V.	2, 1, 7, 10, 2, 13	35 or 42·1 per cent.
13 per cent. or 15	15	DISC.	10	10 or 12 per cent.
27 per cent. or 31	14, 5, 2, 2, 4, 4	II. L.V.	4, 7, 2, 2, 11, 5, 3, 2	36 or 43·3 per cent.
·8 per cent. or 1	1*	DISC.	1	1 or 1·2 per cent.
·8 per cent. or 1	1	III. L.V.		
Total 115				83

The blocks representing the vertebræ have been subdivided into quarters, and the figures on the lines and interspaces represent the number of instances in which the spinal cord terminated at that particular point,—the males being arranged on the left of the figure, the females on the right, in order to simplify as far as possible the statement of the results. The sum of the figures opposite each vertebral body is given along with the percentage of occurrence.

A glance at the table will show that there is a greater tendency for the cord to reach a lower level in the female than in the male. Thus, whilst the cord terminates in 43 per cent. of cases in the female opposite the II lumbar vertebra, it only reaches this level in the male in 27 per cent. of cases. In the female the chances of its terminating opposite the I and II lumbar vertebræ are just about equal (42 and 43 per cent.), whilst in the male the chances are just double that it will terminate opposite the level of the I lumbar vertebra (54 per cent. opposite I lumbar vertebra and 27 per cent. opposite II lumbar vertebra).

Two cases are recorded in which the cord in males terminated as high as the XII dorsal vertebra, whilst in females the highest point attained was the disc between the XII dorsal and I lumbar vertebra. The lowest point reached by the cord was noted in a male as occurring on a level with the upper border of the III lumbar vertebra. The case is recorded by Mr H. J. Waring, F.R.C.S., in his report from St Bartholomew's Hospital.

The case (a male) marked with an asterisk opposite the disc between the II and III lumbar vertebræ is interesting: it might perhaps with more propriety have been placed opposite the disc between the I and II lumbar vertebræ, as the II and III lumbar vertebræ are in reality the XX and XXI vertebral segments. The discrepancy, as Dr Tennant, of Belfast, points out in his notes, is due to the fact that there were only eleven ribs on either side, the number of lumbar vertebræ being thereby increased.

The condition of the cord was examined by Dr Baxter Tyrie, of the Yorkshire College, Leeds, in four fœtuses at term. In these he found the cord terminating opposite the upper border of the III lumbar vertebra in two, at the middle of the III lumbar in one, and at the lower border of the same vertebra in one. He further adds:—"As far as I have been able to observe in the above cases, the position of the termination is dependent on the shape of the conus medullaris, which seems to vary considerably in shape in different subjects. It may be quite short or may be considerably prolonged. In one specimen in my possession it is 2 inches long."

Mr J. Herbert Moorhead, of Trinity College, Dublin, has furnished an exhaustive report on the subjects he examined—40 adults (17 male 23 female) and 5 fœtuses (2 ♂ and 3 ♀). Subjoined are his observations.

Limits of Variability of Spinal Cord.

"The point of termination of the spinal cord varies in *males* from a point 5 mm. above the lower border of the last dorsal vertebra to a

point 1 cm. below the upper border of the 2nd lumbar vertebra; and in *females*, from a point 1·5 cm. below the upper border of the 1st lumbar vertebra to the level of the lower border of the 2nd lumbar vertebra.

The *highest level* of the *end* of the cord occurred in a *male* subject, and was situated 5 mm. above the lower border of the last dorsal vertebra. (In this subject there was marked backward curvature of the spine in the upper dorsal region.) The lowest level occurring in a *female* subject was opposite the lower border of the 2nd lumbar vertebra.

As the most usual situation of the lower end of the cord on the 1st lumbar vertebra is in both sexes the lower 3rd, and on the 2nd lumbar vertebra is the upper 3rd, it is evident that about 1·2 cms. measured up and down from the inter-vertebral disc between the 1st and 2nd lumbar vertebræ would in 60 per cent. of all cases include the termination of the cord.

Point of Termination of Cord in Fœtuses.

Five fœtuses were examined, and in *all of them* the cord was found to descend to an *unusually low* point. In one *male* fœtus of about six months the cord descended to the lower border of the 2nd lumbar vertebra. In another, at full time, the end of the cord reached the lower border of the 3rd lumbar vertebra: the latter was an anencephalus.

Three *female* fœtuses were also examined. Of these, one aged six months was found to have the cord reaching the lower border of the 2nd lumbar vertebra.

In the other two, each about five months old, the point of termination of the cord was situated at the lower borders of the 3rd and *4th* lumbar vertebræ respectively.

Point of Termination of Cord affected by Curves.

Unusually pronounced *lateral* curves of the spinal column may possibly have some effect on the position of the lower end of the cord, since in many cases in which unnatural lateral curves were observed, the cord undoubtedly ended at a higher point than usual. But as this also happened in many cases in which no such abnormal curves were present, no conclusions of any value can be arrived at on the subject.

In one instance in which there was marked *backward* curvature of the spine in the upper part of the dorsal region, the cord ended at an unusually high level, viz., ½ cm. above the lower border of the 12th dorsal vertebra. This high point of termination was *not* due to an abnormally short cord, the measurement of the cord being 44·7 cms.,—that is, only 3 mm. shorter than the average.

Peculiarities in Female Subjects.

The spinal cord has a marked tendency to descend *lower* in *females* than in males. This tendency may be partly explained by the fact

that, *relatively* to the *length* of the *spinal column*, the cord is *slightly longer* in females (as is shown below); in all probability it is also in part due to sexual peculiarity. Moreover, in females, as contrasted with males, we find much greater inconstancy as regards the point of termination, length, and other measurements.

If we take the *average* length of the cord at different points of termination, it seems that the average length is greater in cords which descend low down in the spinal canal (not true of individual subjects). Thus, in *males* the average length of cords which end on and below the lower 3rd of the 1st lumbar vertebra is 45·4 cms., and in cords ending above this point is only 44·5 cms. In *females* the average length of cords ending on the 2nd lumbar vertebra is 44·8 cms., and on the 1st lumbar vertebra is 42·3 cms.

Length of the Spinal Cord.

As a general rule, as might be expected, the cord is longer, *absolutely*, in males than in females; yet the longest cord occurred in a female subject, and measured 47 cms., the longest male cord measuring 46·5 cms.

Curiously enough, however, *relatively* to the average length of the spinal column, as measured from the foramen magnum to the base of the sacrum, the cord is found to be *slightly longer* in *females* than in males. For—

If the average length of the spinal column in males be represented by	100
The proportionate length of the male cord is . .	77·1
While if the spinal column in *females* is represented by .	100
The corresponding length of the *female* cord is . .	79

[Or, to express it differently,—

Male column,	=	100
Female ,,	=	94·8
Male cord,	=	100
Female ,,	=	97·1]

The *limits* of *variability* in the length of the cord are in males from 43·5 cms. to 46·5 cms., and in females from 39·5 cms. to 47 cms. The *tendency* to *variation* is much *greater* in *females* than in males.

The *average length* of the spinal cord in adult males is 45 cms. (in one male aged 14 the cord measured 34·4 cms.). The average length in adult females is 43·7 cms.

The normal length of the cord is usually said to be 18 inches (45·7 cms.). This length, however, was only attained in 20 per cent. of male and 10·5 per cent. of female subjects.

The longest cords generally occur in the tallest subjects: this is, however, by no means constant (*e.g.*, in one male subject whose height was 5 feet 10 inches the cord measured 43·5 cms., while in

another whose height was 5 feet 5 inches the length of the cord was 45 cms.). There seems to be no definite ratio between the length of the cord and the height in any individual subject; but if we take the *average length* of the cord for different heights, we generally find that the length varies somewhat in direct proportion to the height.

Thus in *males*—

For Heights of Ft.	Ins.	Average length of Cord.
5	9	45·7 cms.
5	8	
5	7	44·9 „
5	6	

And in *Females*—

Ft.	Ins.	Average length of Cord.
5	6	45·6 cms.
5	5	
5	4	44·8 „
5	3	

The following table shows the relation found in the female subjects examined between the average length of the cord and the height.

Height. Ft.	Ins.	Average length of Cord.
5	2	41 cms.
5	3	45 „
5	4	43·6 „
5	5	45·3 „
5	6	46·5 „

Length of the Spinal Column, measured from the Foramen magnum to the Base of the Sacrum.

The average length of the spinal column in male subjects is 58·3 cms., and in female subjects is 55·3 cms. The ratio of the average length of the column to the average height is practically the *same* in *males* and *females*. For if 100
represent the height in males, then corresponding length of male column, ... 34·3
And if the height in females be represented by . . 100
the length of the female column is . . . . 34·8
So that the average length of the column bears the same relation to the average height in females as in males.

The average length of the spinal column in each sex seems to bear a direct relationship to the height, as may be seen from the following table, which gives the *average* length of the column for the various heights of the subjects examined:—

Males.

Height. Ft.	Ins.	Average length of Column for this height.
5	6	56 cms.
5	7	58·1 „
5	8	60·5 „
5	9	60·7 „

Females.

Height. Ft.	Ins.	Average length of Column for this height.
5	2	53·3 cms.
5	3	55·2 „
5	4	55·8 „
5	5	57·5 „

The *average distance from the termination* of the cord to the base of the sacrum is 13·4 cms. in males and 11·7 cms. in females. The smaller distance in females may be explained not only by the fact that the cord commonly descends lower than in males, but also by the average height being less in the former sex.

The average height of males examined was 5 ft. 7 in., and of females was 5 ft. 3 in.

The average depth of the upper lumbar vertebræ is 3·3 cms.

In conclusion, from a consideration of the foregoing facts, in so far as they may be relied upon, expressing, as they do, only the results of the examination of a limited number of subjects, it seems evident, since we are compelled to resort to averages in order to show any relation between the point of termination of the cord and its other characteristics, that in any isolated case it is impossible to say what modifying influence may be exerted on the level of the lower end of the cord by the curves of the spinal column, the height of the subject, or the length of the cord itself. The actual point of termination is, in all probability, influenced by a combination of circumstances, of which one of the most important is individual or sexual peculiarity."

Question IV.

To note the level of the bifurcation of the common iliac arteries.

Returns have been received from—

Messrs P. M. Yearsley, Westminster Hospital; P. P. Smith, Trinity College, Dublin; R. P. Farnan, Catholic University Medical School, Dublin; F. G. Parsons, St Thomas' Hospital; J. G. Hayward, St Bartholomew's Hospital; J. J. Urwin, University of Glasgow; G. B. M. White, University College, London; Charles Gibb, Charing

Cross Hospital; J. B. Yeoman, University of Edinburgh; H. L. Hatch, University of Durham College of Medicine, Newcastle-on-Tyne; W. H. Whitehouse, Mason College, Birmingham; A. V. Davies, The Owens College, Manchester; A. Thomson, University of Oxford; G. Barclay Smith, University of Cambridge; and Mrs Percy Flemming and Miss Piercy, of the London School of Medicine for Women.

Records of the examination of 181 subjects (118 ♂ and 63 ♀) have been supplied; in nearly every case the two sides have been examined. The results are shown in Table III.: the males have been kept distinct from the females.

The highest level at which the artery was observed to bifurcate, at a point opposite the middle of the IV l.v., was in a male subject on the left side, recorded by Mr H. Lincoln Hatch, M.R.C.S., in his return from the University of Durham College of Medicine. The lowest level was noted in a female on the right side by Mr W. H. Whitehouse, of Mason College, Birmingham, who found the artery dividing as low as the lower border of the I sacral segment. The tables show that there is a tendency for the left arteries to bifurcate at a lower level than the right: thus, in the males, 31 per cent. of the vessels on the left side bifurcated about the level of the I sacral vertebra, whereas on the right side there were only about 19 per cent.; likewise in the female there are 27 per cent. on the left side on a level with the I sacral segment, whilst on the right the figures yield a percentage of 17. This difference in the levels of bifurcation of the two arteries may perhaps be accounted for by the presence of the coils of the sigmoid flexure of the colon on the left side.

Mr J. G. Hayward, F.R.C.S., of St Bartholomew's Hospital, points out that in the position in which the cadaver usually lies, with a block underneath the shoulders and pelvis, a line drawn between the anterior-superior spines of the ilia corresponds very nearly to the intervertebral disc between the body of the V lumbar vertebra and the sacrum, and it is on or close to this level that the bifurcation usually takes place.

Additional information has been supplied by Messrs Howden, Hayward, E. B. Smith, and G. B. M. Wood in regard to the length of the vessels on either side. The figures supplied by these gentlemen work out as follows:—

Average length of	right	common iliac,	males,	2·34	inches.
,,	,,	,,	females,	2·45	,,
,,	,,	,,	mixed,	2·39	,,
,,	left	,,	males,	2·41	,,
,,	,,	,,	females,	2·47	,,
,,	,,	,,	mixed,	2·44	,,

As would be expected, the length of the arteries is slightly greater in the females than in the males; the arteries on the left side display an average length greater than that of the right side.

Dr Barclay Smith, of the University of Cambridge, notes the maximum length of the artery on the right side as 92 mm., whilst the minimum length he observed was 30 mm. On the left side he

Table III.—*Level of Bifurcation*

Males.

Right.				Left.
·8 per cent. or 1		—IV. L.V.—	1	2 or 1·7 per cent.
	1		1	
·8 per cent. or 1	1	DISC.		
	4		3	
	3		4	
	1		1	
	3		2	
46·6 per cent. or 55	6	—V. L.V.—	3	42 or 36·2 per cent.
	4		4	
	9		3	
	25		22	
32·2 per cent. or 38	38	DISC.	36	36 or 31 per cent.
	10		18	
	8		9	
	1		3	
			4	
19·4 per cent. or 23	2	—I. S.V.—		36 or 31 per cent.
	1		2	
	1			
Total,	118		116	

of Common Iliac Arteries.

FEMALES.

Right.				Left.
		IV. L.V.		1 or 1·5 per cent.
			1	
1·5 per cent. or 1	1	DISC.	1	1 or 1·5 per cent.
	4			
	1		1	
	1			
	1			
			1	
56·2 per cent. or 36	9	V. L.V.	6	31 or 49·2 per cent.
	2			
			1	
			1	
	2		4	
	16		17	
25 per cent. or 16	16	DISC.	13	13 or 20·6 per cent.
	7		9	
	1		2	
			1	
	1		2	
17·2 per cent. or 11	1	I. S.V.	3	17 or 27 per cent.
	1			
Total,	64		63	

TABLE IV.—*Level of Bifurcation*

Males.				Females.
		III. L.V.		
2·7 per cent. or 1	1	DISC.		
72·2 per cent. or 26	1	IV. L.V.		30 or 88·2 per cent.
	4		7	
	12		7	
	9		14	
			2	
22·2 per cent. or 8	8	DISC.	4	4 or 11·7 per cent.
2·7 per cent. or 1	1	V. L.V.		
Total 36				34

of the Abdominal Aorta.

Males and Females.

III. L.V.

DISC. 2 — 2 or 1·6 per cent.

IV. L.V.

1
12
2
28 — 94 or 78·3 per cent.
49
2

DISC. 20 — 20 or 16·6 per cent.

V. L.V.

2
2 — 4 or 3·3 per cent.

Total 120

found a maximum length of 96 mm., whilst the minimum was represented by an artery 36 mm. in length.

Mr J. G. Hayward, F.R.C.S., of St Bartholomew's Hospital, records two instances of unusual length of these vessels: in one subject in which they measured 4½ and 4¼ inches respectively on the right and left sides, the vessels were remarkably tortuous; but in the other subject, although they measured 4½ and 4 inches respectively on the right and left sides, they were not tortuous. Both the subjects were males.

Mr G. B. M. White, of University College, London, notes the occurrence of vessels of 1 inch in length on the right side (1), and two instances of vessels measuring 3¼ inches on the left. Dr Urwin, of the University of Glasgow, found the maximum length in males to be 3½ inches, whilst in females it was 3 inches, the minimum lengths being 2 inches alike in males and females. In males he found the—

Right artery longer than the left in	2	cases.
" " equal in length to the left in	2	"
Left artery longer than the right in	10	"

In females the

Right artery longer than left in	3	"
Left " " right in	1	"

In addition to the foregoing information, the following gentlemen have furnished statistics with regard to the level of the bifurcation of the abdominal aorta:—

Messrs P. P. Smith, of Trinity College, Dublin; J. G. Hayward, of St Bartholomew's Hospital; G. B. M. White, of University College, London; R. P. Farnan, Catholic University Medical School, Dublin; J. T. Urwin, of the University of Glasgow.

The results are represented in Table IV. As in the previous tables, the vertebræ are divided into fourths, the figures on the lines and interspaces denoting the number of cases in which the aorta bifurcated at that level. The results speak for themselves. There appears to be a greater range of variation in the males than in the females.

In an elaborate return dealing with this subject, Mr Peers Peers-Smith, of Trinity College, Dublin, reports as follows:—

"The following table represents the average height of male and female subjects at the different points of bifurcation:—

Position.	Females.	Males.
Upper third of 4th Lumbar V,	5ft. 4in.	5ft. 5in.
Middle third of 4th Lumbar V,	5 5	5 7
Lower third of 4th Lumbar V,	5 3	5 8
Intervertebral Disc between 4th and 5th Lumbar V,	5 4	5 8

The following table will show the relation between the various levels of bifurcation and the height of the subject in each sex:—

MALES.

For Heights of 5ft. 9in. and 5ft. 8in.

Situation—

Lower third of 4th Lumbar Vertebra,	66·6	per cent.
On Intervertebral Disc between 4th and 5th Lumbar,	22·2	„
Upper third of 4th Lumbar Vertebra,	11·2	„

For Heights of 5ft. 7in. and 5ft. 6in.

Situation—

Middle third of 4th Lumbar,	50	per cent.
Intervertebral Disc between 4th and 5th Lumbar Vertebræ,	37·5	„
Lower third of 4th Lumbar,	12·5	„

FEMALES.

For Heights of 5ft. 6in. and 5ft. 5in.

Situation—

On lower third of 4th Lumbar,	50	per cent.
On upper third of 4th Lumbar,	25	„
On Intervertebral Disc between 4th and 5th Lumbar Vertebræ,	25	„

For Heights of 5ft. 4in. and 5ft. 3in.

Situation—

On lower third of 4th Lumbar,	40	per cent.
On upper third of 4th Lumbar,	30	„
On Intervertebral Disc between 4th and 5th Lumbar Vertebræ,	20	„
On middle third of 4th Lumbar,	10	„

For Heights of 5ft. 2in. and 5ft. 1in.

Situation—

On lower third of 4th Lumbar,	75	per cent.
On middle third of 4th Lumbar,	25	„

Thus it is seen *that the taller the male subject the greater the tendency for the bifurcation to be at a lower level. But in females the tendency, if any, is in the opposite direction.*

In the only male subject of 5ft. 10in. the bifurcation was on the intervertebral disc between the 4th and 5th Lumbar; and in one of only 4ft. 5in. it was on the lower third of the 4th Lumbar.

In one male of 5ft. 5in. the bifurcation was on the upper third of

the 5th lumbar vertebra: in this case nothing could be found to account for the peculiarity. But in a female of 5ft. 4in., in which the same peculiarity was found, a very pronounced lateral curvature of the spinal column was present.

In a male case of 5ft. 9in. the bifurcation was on the intervertebral disc between the 3rd and 4th lumbar vertebræ. In this case also nothing could be found to account for the high level of bifurcation.

In one female case of 5ft. 3in., in which the right internal iliac artery came off at the level of the upper half of the 5th lumbar vertebra, the bifurcation was on the upper third of the 4th. Also, in another case, in which there was exactly the same high origin of this artery, there was nothing peculiar about the level of bifurcation.

A most frequent occurrence, and one that at first sight might appear to have some influence on the level of bifurcation, is, that in a good many of the subjects examined, two to four left renal arteries were found coming off separately from the aorta. Yet these in no way had any influence on the place of bifurcation.

Indeed, it seems that neither peculiarities with regard to the branches of the artery nor any curvatures of the spinal column have anything to say to the level of the bifurcation of the abdominal aorta. The only thing, in fact, that seems to have any bearing on its situation is the height of the subject."

In presenting this their Fifth Annual Report, the Committee desire to express their thanks to the numerous gentlemen who have so kindly assisted them. During the past five years the scheme has had the support of the most important anatomical institutions in the country. The Committee look forward with confidence to a continuance of that co-operation on the part of the teachers of anatomy which has enabled them to publish their past reports.

The Secretary will be glad to receive any suggestions from members of the Society, and will submit any recommendations as to fresh inquiries to the Committee of Collective Investigation. All communications relative to this subject should be addressed to the Secretary, Collective Investigation Committee, Department of Human Anatomy, Museum, Oxford.

OBSERVATIONS ON THE URINARY BLADDER AND URETHRA. PART II. THE NERVES. By JOSEPH GRIFFITHS, M.A. (Cantab.), M.D. (Edin.), F.R.C.S. (Eng.), *Assistant to the Professor of Surgery in the University of Cambridge.*

(*Continued from* Vol. XXV. p. 549.)

IN the part of the memoir that has already appeared in this *Journal*, I gave an account of the arrangement of the muscular fibres in the wall of the urinary bladder, and of the disposition of the striped muscle around the urethra. In the case of the urinary bladder it was pointed out that the muscular fibres do not run in two or three different planes (external, middle, and internal)—the fibres running in different directions in each plane—but that the fibres run from one direction to another, and also from one plane to another; so that fibres which are longitudinal in an external plane at one point may be circular in their direction, and in an internal plane at another. Further, it was shown that there exists no thickening, composed of muscular fibres disposed circularly, at the neck of the bladder either in Man or in the lower animals. In the case of the urethra it was shown that the external sphincter of Henle is merely the commencement of the constrictor urethræ, and that this sheet of striped muscle begins near the point of entrance into the urethra of the genital ducts; that it largely depends for its growth and size upon the presence or absence of the essential genital organs, the testes; and that in rutting animals the striped muscle of the urethra increases in size with the onset of the rutting period, remains of large size during that period, and diminishes with its decline, remaining during the non-rutting season (*i.e.*, the greater part of the year) of small size. While the rutting season is at its height the muscular fibres of this sheet of muscle are large and fully developed, but during the non-rutting period they are small and atrophied.

Having thus given an account of the disposition of the muscular fibres in the wall of the bladder, and of the striped muscle

of the urethra, it remains to describe briefly the nerves that supply these parts, before giving the result of an inquiry into the functions of each nerve, and drawing some conclusions regarding the mechanism of the retention and expulsion of urine.

The Nerves of the Bladder and Urethra.

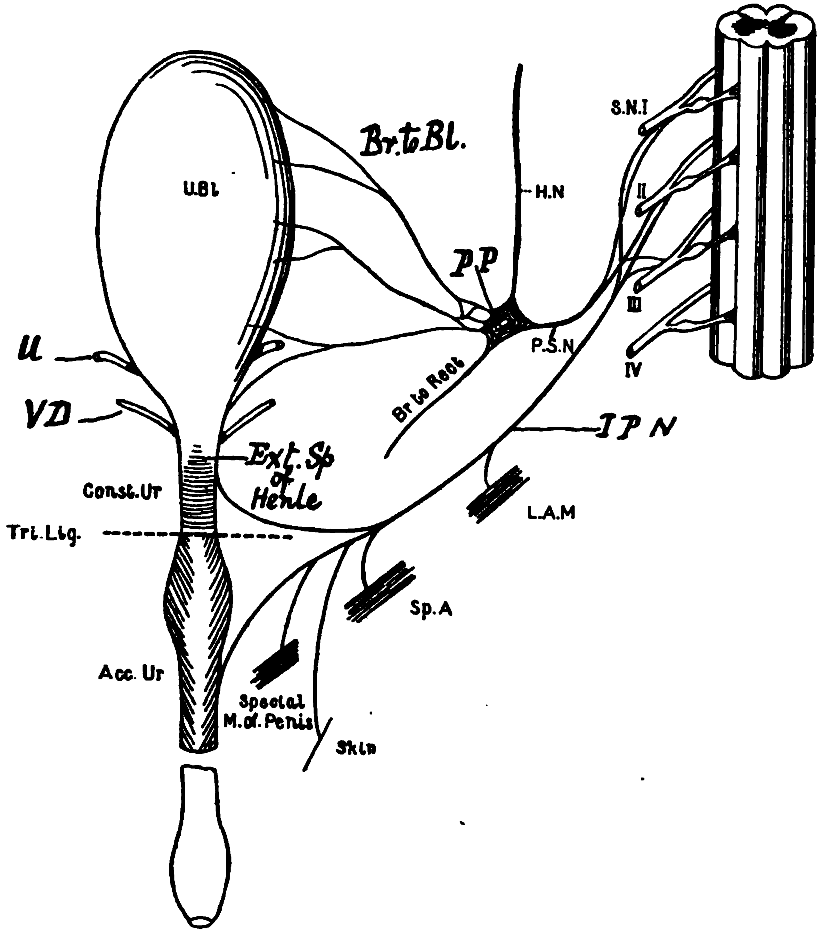
The following account is taken chiefly from my own dissections in the Dog.

Although the urinary bladder is a single and unpaired organ, yet it, as well as the rectum and urethra, has a bilateral supply of nerves just as it has a bilateral vascular supply; there being two sets of nerves, one on each side. Not only is there a set of nerves on each side, but each set is subdivided into two, one coming *directly* from the sacral part of the spinal cord, and the other *indirectly* from the dorsal and lumbar cord, through the abdominal sympathetic system of nerves; both sets uniting together before being distributed to the corresponding half of the organ. These nerves are known respectively as the pelvic splanchnic (*nervus erigens*) and the hygogastric. Further, the pudic (internal pudic of Man) supplies the nerves to the urethral mucous membrane, and to the muscles of the urethra and penis as well as to the sphincter and levator ani.

Pelvic Splanchnic.

The pelvic splanchnic (*nervus erigens*) is a small white nerve which arises usually by two roots, one large and the other small. The large root arises from the *second* sacral nerve, and the small root usually from the *first*, but sometimes from the *third*. Occasionally two small roots (in addition to the large root) are found, one arising from the *first* and the other from the *third* sacral nerves. These roots, two or it may be three in number, soon join to form a small white cord, which courses forwards on the side of the rectum, near the fore part of which it is joined by the hypogastric nerve in the peritoneal fold which attaches the sides of the bladder to the lateral wall of the pelvis. Where the two nerves join there is usually a large flat ganglion, from which many fine nerve fibres arise. One of these fibres is larger

than the rest, and passes downwards on the side of the rectum, into which, after a course varying from 1 to 2 inches, it enters, and is soon lost among the muscle-fibres. The remaining



EXPLANATION OF SCHEMATIC FIGURE:—

UBl, urinary bladder; *Const Ur*, constrictor urethræ; *Acc Ur*, accelerator urinæ; *Tri Lig*, triangular ligament; *U*, ureters; *VD*, vas deferens; *HN*, hypogastric nerve; *PSN*, pelvic splanchnic (nervus erigens); *SN*, I, II, III, IV, sacral nerves; *PP*, pelvic plexus; *IPN*, internal pudic nerve; *LAM*, levator ani muscle; *Sp A*, sphincter ani.

fibres are small. Soon after leaving the ganglion they join with one another to form a plexus of nerves, including numerous

smaller ganglia which can just be seen with the naked eye. This plexus in the human subject is termed by Tiedemann the "plexus gangliosa." Soon these fibres join again to form the terminal nerves, the shortest of which are about an inch in length.[1] These terminal fibres, which can be easily separated from one another along nearly the whole length, may be divided, for convenience, into three sets: one of these sets supplies the upper end or fundus of the bladder, a second supplies the main parts of the body, and a third supplies the neck and *first* or urinary portion of the urethra. Further, each set is made up of a number of nerves, each of which supplies a particular portion of the bladder-wall. Among the fibres that pass to the region of the neck of the bladder are those which proceed to the *first* or urinary portion of the urethra, on the anterior or ventral wall of which they may be seen descending, and, after a short course, disappearing into its substance. In the female, additional fibres exist for supplying the uterus and vagina. These pass along with those for the neck of the bladder, some being deflected backwards on to the body of the uterus, and the remainder descend on the walls of the vagina which they supply.

The trunk of the pelvic splanchnic nerve consists almost entirely of small medullated nerve fibres measuring from 2 to 3 μ in diameter; but there are in addition a few medium-sized medullated fibres of about 7 μ in diameter. All these medullated fibres lose their medulla, as we shall presently see, in the ganglia of the plexus, the nerves beyond the ganglia consisting only of nerve fibres devoid of a medullary sheath.

Hypogastric Nerve.

The hypogastric is a long slender grey nerve which descends into the pelvis from the abdomen in front of the bodies of the lumbar vertebræ. In the pelvis it joins, as pointed out above, with the pelvic splanchnic of the same side to form a large ganglion from which the nerve to the rectum and the branches

[1] In Man the vesical branches of the sacral plexus are derived from the 2nd, 3rd, and 4th sacral nerves, but chiefly from the 3rd, according to Tiedemann (see *Quain's Anat.*, 10th ed.).

to the vesical plexus arise. This nerve takes origin from one of the lower ends of the mesenteric ganglion, which is composed of two more or less equal elongated parts, connected together by numerous small transverse fibres, and which surrounds the origin of the inferior mesenteric artery. Into these paired ganglia descend two or more fibres from the pre-aortic plexus, and two or three visceral branches from the lumbar part of the sympathetic cord. The hypogastric nerve is composed in the main of non-medullated nerve fibres; it has, however, one or two large medullated fibres, which stand out prominently among the grey fibres. In Man this nerve is represented by a leash of grey fibres running downwards in front of the vertebral column.

Pudic Nerve.

The pudic nerve in the Dog corresponds in the main to the internal pudic of Man, but also in part to the small sciatic.[1] It takes origin from much the same nerve roots as the pelvic splanchnic, namely, the chief root from the *second* sacral nerve, with additional slender roots from the *first* and *third.* All the roots soon join to form the trunk, which is large and white like an ordinary skeletal nerve. The trunk passes outwards to reach the external surface of the levator ani muscle, along which it runs forwards towards the under part of the symphysis pubis, and there enters the penis. Along its course it gives off several branches, especially to the striped muscles of the pelvis and to those that surround the anus and urethra, as well as to the special muscles of the penis. The first branch given off is at the anterior or ventral border of the levator ani, where it turns round that border so as to reach the inner surface of the muscle. The next is a longish branch, which is directed in the main backwards to reach the external sphincter ani, in the substance of which it is distributed. Just beyond this, two or more long and slender branches are given off. These pass forwards to reach the urethra, on the anterior or ventral surface of which they pass towards the prostate gland; and they supply the striped muscles surrounding the intrapelvic portion of the

[1] The internal pudic nerve in Man arises from the 1st, 2nd, and 3rd sacral nerves, one segment more forward in the series than the pelvic splanchnic.

genital part of the urethra, namely, the external sphincter of Henle and the constrictor urethræ. The trunk of the nerve then leaves the pelvis and courses along the penis, in which it ends; but before doing so it gives off branches to supply all the special muscles of that organ. In addition to supplying these muscles with motor fibres, it acts as the sensory nerve of the skin of the penis, mucous membrane of the urethra, and the skin of the perineum. The nerve fibres in the trunk of this nerve are almost entirely large medullated fibres, measuring about 12 μ in diameter, but there are also a few groups, of eight to twelve in number, of small medullated fibres, measuring 2 to 3 μ in diameter. The branches to the muscles are almost exclusively composed of the large medullated fibres.

The Effect of Stimulation of the Nerves going to the Bladder and Urethra.

Owing to the fact that the pelvic viscera in the Dog, and especially the nerves which supply them, are difficult to expose, it was found necessary to devise some plan by means of which the contents of the pelvis could be well displayed and rendered easily accessible without causing injury to blood-vessels or nerves. After a few unsuccessful attempts in the dead animal, I found that in order to lay open the pelvic cavity and expose the pelvic viscera with their blood-vessels and nerves, all that is necessary is to divide the symphysis pubis, and then separate both sacro-iliac synchondroses by forcibly turning the iliac bones outwards. By this means the pubic bones may be separated 2 inches and more, and the pelvic viscera fully exposed. The blood-vessels and nerves of these viscera, which will not have been injured, may then be dissected in the greater part of their length. In short, all the pelvic viscera are fully exposed from the front for experiments on the bladder, uterus and vagina, or rectum. The details of the procedure are as follows:—

The dog, being fully anæsthetised, is laid upon his back, and then secured in the usual way. An incision, extending from the umbilicus to the hinder border of the *symphysis pubis* (passing on one side of the penis in the male), and reaching down to the peritoneum, is then made. The symphysis is cut by means of a

strong knife, or sawn, when ossified, by a small hand-saw, care being taken to avoid injury to the dorsal veins of the penis in the male and a plexus of veins from the clitoris in the female. If some of these vessels be torn, bleeding is apt to be troublesome and difficult to control. By placing a small block of wood under the sacrum, and forcibly turning the iliac bones outwards, so as to produce a fracture-dislocation at the sacro-iliac synchondrosis, the pubic bones can be separated to the extent of 2 to 3 inches. The connections of the urethra with the pubic bones should now be carefully separated by the knife. The bladder, covered in nearly its whole extent with peritoneum, the urethra, and rectum are thus fully exposed and rendered easily accessible; and after removing, by means of two pairs of dissecting forceps, the pad of fat which lies on each side of the neck of the bladder and first part of the urethra, the nerves accompanying the blood-vessels are fully brought into view. The bladder itself may now be fully exposed by cutting or tearing the peritoneum, which lies in front of its upper part; but this should not be undertaken until all other preparations are complete, for cold air is very liable to induce a state of more or less tonic contraction of its walls, and render the bladder unfit for experiment. In each experiment a slender glass cannula was introduced along the urethra into the interior of the bladder and secured by a ligature. From the cannula a short length of narrow indiarubber tube led into warm water contained in a small graduated glass reservoir, which was placed a little above the level of the bladder. Thus the bladder could empty itself or be refilled, and even distended, by simply raising the level of water in the reservoir. Before adopting this simple arrangement I was in the habit of using a water manometer, with a recording apparatus attached thereto; but I soon found that the best and most satisfactory method of observing the effects of stimulation of the nerves on the bladder was by watching the movements of the exposed organ with the naked eye. All the effects herein recorded were observed in that way, except the variations in the tension of the muscular wall of the bladder, which, being small, can only be satisfactorily studied by means of a water manometer.

The Pelvic Splanchnic Nerve (Nervus Erigens).

With a little care the trunk of the pelvic splanchnic nerve, on one or on both sides, may be exposed for a half or three-quarters of an inch; and it can without much difficulty be separated from the accompanying artery and vein.

If one nerve, say the left, be dissected, and a pair of electrodes connected with the secondary coil of a Du Bois Reymond induction apparatus, through which passes a current of such a strength as can be easily borne on the tip of the tongue, be applied to it in its continuity, there occur, *first*, contraction of the bladder, and *secondly*, reflex disturbances of the central nervous system—the latter manifesting themselves chiefly in inspiratory dyspnœa. It will therefore be convenient to give here the results obtained under the two following headings:—

I. The effects upon the bladder.
II. The effects upon the central nervous system.

I. *The Effects of Stimulation of the Pelvic Splanchnic Nerve upon the Bladder.*

The effects of stimulation of the pelvic splanchnic nerve upon the bladder may best be studied by stimulating the nerve (1) in its continuity, (2) at its peripheral, and (3) at its central end when divided. This plan has been adopted in this inquiry.

(1) *Stimulation of the Pelvic Splanchnic Nerve in its Continuity.*

A close examination with the naked eye of the effects upon the bladder of stimulation of one pelvic splanchnic nerve in its continuity, shows that the resulting contraction is peculiar, inasmuch as it does not affect the whole organ equally, being chiefly confined to the lateral half that corresponds to the nerve stimulated. In other words, stimulation of the *left* nerve causes marked contraction in the left half of the bladder. This contraction of the bladder, although chiefly confined to one half, is usually followed by the expulsion of a certain quantity of urine. The contraction, however, is not strictly confined to one half, but is often, though not always, accompanied by contraction of

a smaller degree in the opposite half. Although the opposite half usually contracts a little, yet it is invariably bulged outwards by the increased intravesical pressure caused by the limited but marked contraction of the other half.

The contraction of the half of the bladder opposite to that on which the nerve is stimulated can be quite abolished in one of two ways, namely, (1) by dividing the trunk of the opposite pelvic splanchnic nerve, (2) by dividing the nerve itself [to which the electrodes are applied] proximally to the point of application of the stimulus. Accordingly, the contraction of the half of the bladder opposite to that on which the nerve is stimulated is probably dependent upon a reflex through the lumbo-sacral part of the spinal cord, the efferent stimulus passing along the opposite and intact pelvic splanchnic nerve to the bladder. Division of the *hypogastric* nerve on one or on both sides produces no influence upon this reflex. Further reference will be made to this later on.

(2) *Stimulation of the Peripheral End of the Divided Pelvic Splanchnic Nerve.*

When the peripheral end of the divided nerve is stimulated, the contraction differs from that which is described above in being wholly limited to the corresponding half of the bladder. Stimulation of the *left* nerve produces contraction of the *left* half only; of the *right*, the *right* half only. During contraction of the one half, the opposite remains relaxed, and owing to the increase of intravesical pressure it is not unfrequently considerably bulged outwards. Under these circumstances the bladder assumes a very peculiar shape, one side being shortened and drawn in, while the opposite is bulged and convex, the apex of the organ being, in consequence, much drawn to the contracted side.

The bladder-wall on the contracted side is, therefore, both shortened and drawn in: the shortening is produced by the contraction of the external and longitudinally disposed muscular fasciculi, and the indrawing is produced by contraction of the inner obliquely and circularly disposed muscular fasciculi. Thus the contraction involves all the layers of muscle in the wall on that side, that is, the longitudinal, circular, and oblique, all of

which participate equally in the contraction. Fellner and Von Basch[1] found that stimulation of the pelvic splanchnic (*nervi erigentes*) supplying the rectum produced contraction of the longitudinal, and stimulation of the hypogastric nerve, contraction of the circular coats. Gaskell[2] and others think it may be the same in the bladder, that is to say, that stimulation of the pelvic splanchnic produces contraction of the longitudinal fibres (detrusor urinæ), and stimulation of the hypogastric, contraction of the circular fibres.

Such a view is, however, negatived by the very arrangement of the muscular fasiculi in the wall of the bladder (Man, Dog, and Cat). The arrangement is such that contraction of one set of fasciculi independently of another is impossible, for the fasciculi run in their course from one plane or stratum into another, from longitudinal to an oblique or transverse direction, and *vice versâ*. For further reference to this subject, see *Journ. of Anat. and Phys.*, vol. xxv. p. 535.

The fact that stimulation of the peripheral end of one divided nerve, say the left, produces contraction of only the left half of the bladder is somewhat remarkable, seeing that the urinary bladder is a median unpaired organ, and that in the higher animals and in Man it shows no trace of any division into two equal lateral parts.

The bilateral nature of the urinary bladder is, however, well illustrated in the tortoise and in the common frog. For in these animals the bladder is so deeply bilobed as to appear when distended like two sacs joined together at or near their necks. Each sac may, as I have observed in each animal during dissection, contract independently of the other. But how far each sac is capable of acting independently of its fellow under normal conditions I am unable to say.

(3) *Stimulation of the Central End of the Divided Pelvic Splanchnic Nerve.*

Stimulation of the central end of the divided pelvic splanchnic nerve (the opposite nerve being intact) produces a slight con-

[1] Fellner and Von Basch, *Med. Jahrb. d. Ges. d. Aertze*, Wien, 1883.
[2] Gaskell, *Jour. of Phys.*, vol. vii.

traction of the bladder, which is often so small as to escape notice by the naked eye. In order to be sure of the occurrence of such small contractions, it is necessary to make use of a water manometer, the movements of which can be easily watched. This contraction takes place even when both hypogastric nerves are divided, the only remaining path to the bladder being the pelvic splanchnic of the opposite side. Division of this latter nerve abolishes the contraction. The contraction is always feeble, but this may perhaps be accounted for by the deep state of anæsthesia in which the animals were kept during the experiments.

Thus the contraction, small as it appears to be when the animal is under the influence of an anæsthetic, may be probably due to a reflex from the spinal cord passing peripherally through the opposite and intact pelvic splanchnic nerve.

Indeed, from the researches of Budge,[1] Gianuzzi,[2] Goltz,[3] and others, we may with safety conclude that such a reflex can be set up, and that the portion of the spinal cord concerned in this reflex is the lumbo-sacral enlargement.

If this view be correct, the pelvic splanchnic nerve may act not only as an *efferent* but also as an *afferent* nerve, conveying impulses to, as well as away from, the central nervous system.

Budge pointed out that the posterior nerve roots of the 1st, 2nd, 3rd, and 4th sacral nerves, especially those of the 1st and 2nd, contained sensory fibres which, when stimulated, gave rise to reflex contraction of the bladder. Sokownin[4] and others have since obtained the same result. This reflex takes place provided the opposite pelvic splanchnic nerve be intact, and it is not influenced by division of one or of both hypogastric nerves. It is, indeed, almost certain that these very sensory fibres found in the posterior nerve roots of the 1st, 2nd, and 3rd sacral nerves are the continuation of the sensory fibres that are found in the trunk of the pelvic splanchnic, which is, no doubt, according to the results of the experiments herein described, the chief sensory nerve to the bladder.

[1] Budge, *Arch. f. d. Ges. Phys.*, Bd. vi.

[2] Gianuzzi, *Jour. de la Phys.*, T. vi., 1863.

[3] Goltz, *Ueber die Functionen des Lendenmarkes des Hundes.* Pflüger's *Arch.* 1874.

[4] Langley, *Jour. of Phys.*, vol. xii.

II. *The Effects of Stimulation of the Pelvic Splanchnic Nerve upon the Central Nervous System.*

It has already been pointed out that stimulation of this nerve, either in its continuity or at its central end, after division produces a reflex contraction of the opposite half of the bladder. But in addition, the following disturbances of the central nervous system take place.

When the nerve is stimulated in its continuity, or only at its central end after division, the first effect observed is, that the inspiratory efforts increase, and continue increasing, both in depth and force, until inspiratory dyspnœa is set up; and then there occurs general convulsive contraction of the muscles of the limbs and trunk. As soon as the stimulus is removed the dyspnœa ceases, and the animal again becomes quiet. The above changes are induced very readily, even with a strength of current that can hardly be felt on the tip of the tongue, and indeed they can be set up as readily as contraction of the bladder. The pelvic splanchnic, therefore, act as afferent as well as efferent nerves; and they conduct afferent as easily, if not more easily, than efferent impulses. In other words, the nerves are sensory as well as motor.

The sensitiveness of this nerve to electrical stimulus is so great that I was strongly reminded of the great sensitiveness of the bladder under various diseased conditions. It may be that the sharp shivering, preceded by a deep inspiration, not unfrequently observed in Man towards the end of micturition (the last contraction of the bladder), is due to stimulation of the terminal branches of this sensitive nerve. The same phenomenon may sometimes be witnessed in horses.

Résumé.

1. Stimulation of the peripheral end of the divided pelvic splanchnic nerve produces contraction of the lateral half of the bladder on the same side as the nerve stimulated. This contraction is powerful, and involves all the layers of muscular fibres in the wall on that side.

2. Stimulation of the central end of the divided nerve produces

reflex contraction, through its fellow of the opposite side, of the half of the bladder on the side opposite to that on which the nerve is stimulated, and also reflex disturbances of the central nervous system, chiefly manifested in inspiratory dyspnœa and general convulsive contractions.

3. Stimulation of the nerve in its continuity produces contraction of the half of the bladder on that side, slighter [reflex] contraction of the other half, and the reflex disturbances of the central nervous system above mentioned.

Therefore, this nerve is not only *motor* to the bladder, and that to the corresponding half only, but also *sensory*, and capable of producing reflex contraction of the bladder, as well as reflex disturbances in the central nervous system.

The Hypogastric Nerves.

By turning the rectum to one side this pair of nerves may be seen running down into the pelvis behind the peritoneum, and lying upon the vertebral column. The two nerves gradually diverge from one another as they pass downwards from the inferior mesenteric ganglion which, although it often appears single, is in reality composed of two lateral parts joined together by connecting branches. A considerable length of each nerve may be thus exposed. Each nerve is in the main composed of non-medullated nerve fibres, but there are usually present a few large medullated fibres.

If one nerve be divided near its middle, and the peripheral end be stimulated, a small contraction of the bladder occurs. This contraction is identical with that produced by stimulation of the peripheral end of the divided pelvic splanchnic nerve; it is limited to the corresponding half of the organ, and it affects equally all the layers of muscular fasciculi, the external longitudinal fibres contracting as well as the internal circular and oblique. Thus the difference between the effect produced by the stimulation of the pelvic splanchnic and of the hypogastric nerves is only one of degree; that produced by stimulation of the hypogastric being less powerful and less extensive, as was first pointed out by Gianuzzi.[1] Since the above experiments

[1] Gianuzzi, *Jour. de la Phys.*, T. vi., 1863.

were performed, Mr Langley[1] has found the same thing, and he has further shown that contraction of the colon and of the rectum in the Rabbit, set up by stimulation of the sympathetic fibres, involves all the coats, both longitudinal and circular, and not the latter only, as was maintained by Fellner and Von Basch[2] and other previous writers.

Contraction of the bladder wall is, however, not the only effect of stimulation of the peripheral end of this nerve; for if the bladder be previously contracted, then stimulation of the nerve produces a small initial contraction which is invisible to the naked eye, and this is quickly followed by a rapid and pronounced relaxation—the relaxation going on until the walls, previously rigid, become quite relaxed and almost flaccid. The initial contraction, though not visible to the naked eye, can be easily demonstrated by connecting the bladder by means of a cannula in the urethra with a water manometer. The relaxation of the wall of the bladder is best shown by first stimulating the peripheral end of the divided pelvic splanchnic nerve with a strong stimulus, so as to induce a tonic contraction of the muscle —a state which can be readily induced, and which, if left alone, is slow to disappear. While the muscle is in this state, stimulation of the hypogastric usually causes a slight initial contraction, which is followed by a rapid and pronounced relaxation. The bladder, which was a few seconds before quite rigid, becomes relaxed, with its walls in a state of flaccidity.

In this sense the nerve may be said to be inhibitory to the bladder; but I was not able to demonstrate satisfactorily, in the many experiments I performed, that stimulation of the hypogastric nerve could inhibit the contraction of the bladder once started by stimulation of the pelvic splanchnic. That is to say, stimulation of the hypogastric nerve during the progress of contraction, induced by stimulation of the pelvic splanchnic, produced no result; but if the hypogastric nerve be stimulated during the tonicity that follows the contraction, then there is a rapid relaxation, preceded by a small initial contraction. Undoubtedly the hypogastric nerve has the power of inducing rapid relaxation of the wall of the bladder when previously in

[1] Langley, *Jour. of Phys.*, vol. xii.
[2] Fellner and Von Basch, *Med. Jahrb. d. Ges. d. Aertze*, Wien, 1883.

a state of rigidity. Langley[1] says that "stimulation of the sympathetic nerve fibres going to the descending colon in the Rabbit causes usually a brief preliminary contraction, and in all cases, soon or at once, a marked inhibition of the movements of the descending colon; the contraction and inhibition affecting both muscular coats."

It would appear, therefore, that the effect of stimulation of the sympathetic fibres in the case of the bladder in the Dog, and in the colon and rectum in the Rabbit, produces an initial contraction whether the muscle be in a state of tonicity (as in the former case) or of slow contraction (as in the latter), which is soon followed by a rapid and pronounced relaxation and cessation of contraction.

Stimulation of the central end of the divided nerve while all the other nerves to the bladder, including its fellow, are intact, produces a slight reflex contraction of the bladder, as is shown by the rise of the level of the water in the manometer. The path of this reflex may be *indirect*, through the spinal cord (lumbo-sacral), and thence peripherally along the pelvic splanchnic nerves, or it may be *direct*, through the inferior mesenteric ganglion, and along the opposite hypogastric nerve. I found in several instances that division of both pelvic splanchnic nerves abolished the reflex, and that division of the opposite hypogastric nerve did not influence it.

Sokownin,[2] however, noted in his experiments that this reflex takes place through the opposite hypogastric nerve, and not through the pelvic splanchnic nerve. He further observed that after complete isolation of the inferior mesenteric ganglion from the pre-vertebral plexus, and from the lumbar portion of the sympathetic cord, this reflex could still be excited just as easily and as well as when all the connections were intact. He, therefore, concluded that the inferior mesenteric ganglion is capable of acting as a reflex centre of the bladder. Nussbaum[3] and others have repeated these experiments and confirmed the results obtained by Sokownin. (See note by Langley and Anderson, *Proc. Phys. Soc.*, 1894.)

[1] Langley, *Jour. of Phys.*, vol. xii.

[2] Sokownin, *Beiträge zur Physiologie der Entleerung und Zurückhaltung der Harns.* Hoff. u. Schwal., *Jahresbericht*, 1878.

[3] Nussbaum. Hoffmann und Schwalbe's *Jahresbericht*, 1880.

There is, however, some doubt still as to the exact path of the reflex, and still more doubt whether the reflex is a spurious or a genuine one.

Nearly all writers upon this subject, from Gianuzzi[1] up to the present, have regarded this nerve as the sensory nerve of the bladder. It may, indeed, act as a sensory nerve, but it can hardly be the chief one, for stimulation of the central end of the divided pelvic splanchnic gives rise to great disturbances in the central nervous system; whereas stimulation of the central end of the divided hypogastric nerve, at any rate under chloroform and morphine anæsthesia, produces no such effects.

Indeed, it may be said that just as the hypogastric nerve is feeble in its motor effects upon the bladder, so it is feeble in its sensory function, in comparison with the pelvic splanchnic nerve.

Further, the hypogastric nerve can hardly be an important sensory nerve to the bladder; for in the well-known experiment performed by Goltz,[2] in which the spinal cord was divided at the junction of the lumbar and dorsal parts of the spinal cord, the hypogastric nerves were no longer in connection with the lumbar part of the cord, yet the bladder, after a few days, performed its function of retaining and expelling urine naturally.

Again, Mosso and Pellicani[3] removed portions of each of these nerves, together with the inferior mesenteric ganglion in dogs, and found that the complete interruption in the nerves thus induced made no difference whatever in the normal action of the bladder.

It may, therefore, be concluded that whatever function this pair of nerves exercises upon the urinary bladder, the normal action of the organ may go on uninterruptedly even when portions of both nerves have been excised, and that the nerve contains motor as well as sensory fibres; further, that when the bladder wall is in a state of tonic contraction, stimulation of the nerve induces, after a small initial contraction, a marked and rapid relaxation.

[1] Gianuzzi, *Jour. de la Phys.*, T. vi., 1863.

[2] Goltz, *Ueber die Functionen des Lendenmarkes des Hundes.* Pflüger's *Arch.*, 1874.

[3] Mosso and Pellicani, *Arch. Ital. de Biol.*, T. i.

THE BRANCHES OF THE PLEXUS.

The vesical branches of the pelvic plexus of nerves may be divided into three sets, an upper, middle, and lower, each set being represented mainly by a nerve sufficiently long to be dissected and isolated from the surrounding smaller branches. I shall therefore, for convenience, always refer to each set as if it were represented by a single branch. Just beyond the point of junction of the pelvic splanchnic and hypogastric nerves the plexus is dense, many of the fibres having on them small ganglia which can only just be seen with the naked eye. It is from this dense plexus that the branches to the bladder and *first* (urinary) part of the urethra proceed. The upper branches supply the upper segment or fundus of the bladder; the middle, the middle segment; and the lower, the region of the neck of the bladder, and the contiguous or first portion of the urethra. All these branches are composed of non-medullated nerves; the medulla of the small fibres of the pelvic splanchnic nerve being lost in the numerous ganglia on the fibres of the plexus. Thus each lateral half of the bladder may be mapped out according to its nerve supply into three regions: (1) an upper segment, (2) a middle segment, and (3) a lower segment which includes the first or urinary portion of the urethra. Just as there is an anatomical limitation, so there is a physiological; for, as will be presently shown, stimulation of the peripheral end of one of these branches after division induces contraction only in the area to which it is distributed, the contraction remaining limited, and not spreading by virtue of the continuity of the muscle-fibres.

If the middle branch be isolated at one part and stimulated *in its continuity*, and the remaining branches be undisturbed, the result is just the same as if the trunk of the pelvic splanchnic nerve were stimulated; that is to say, there occurs (1) marked contraction of the entire corresponding lateral half of the bladder, and (2) reflex disturbances of the central nervous system, chiefly inspiratory dyspnœa. This is as one would expect.

If the same branch be divided, and its *peripheral end* only be stimulated, there occurs a limited contraction of the wall of the

bladder in the middle segment, the contraction being most marked in the centre of that segment, and fading away towards, but not extending into, the neighbouring segments. In this manner the upper, middle, and lower segments of the bladder may be made to contract separately, the physiological influence of each nerve being limited to its area of distribution. This contraction produced by stimulation of the branches of the plexus separately affects, as in the case of the pelvic splanchnic and hypogastric nerves, all the layers of muscular fasciculi in any given segment, and not the external longitudinal or the internal circular coat alone.

On the other hand, if the central end of the same divided branch be stimulated, the result is the same as that obtained by stimulation of the branch in its continuity.

If, however, the *trunk* of the pelvic splanchnic nerve be then divided, and the *central end* of the divided branch be again stimulated, then there occurs only contraction of the corresponding lateral half of the bladder, which contraction must be brought about by communication (through the medium of ganglia) with the fibres of the other branches of the plexus. Further, if both the hypogastric nerves, and in addition the opposite pelvic splanchnic nerve, be divided, the result is the same, namely, unilateral contraction of the bladder on the side of the nerve stimulated. The pelvic plexus may thus be completely isolated from the abdominal sympathetic as well as from the spinal cord, and yet stimulation of the central end of a divided branch of the plexus induces contraction of the corresponding lateral half of the bladder. I have confirmed this on several occasions, and have not as yet failed to elicit the same result. I must here add, however, that stimulation of the central end of the divided rectal branch of the plexus gives no such result, no change whatever being produced.

Is the above result a *spurious* or a *true* reflex? If spurious, it may be due to an escape to all the neighbouring branches of current from the electrodes applied to the branch, or to the occurrence of such an intermingling of fibres running from one ganglion to another that it is impossible to stimulate one set of fibres without at the same time stimulating some, if not all, of the others. That this result is due to an escape of current from

one branch, while it is being stimulated, to all the others cannot be strongly supported; for the same result may be obtained, time after time, in the same animal, with varying degrees of stimulus applied with the utmost care. But whether this be due to such an intermingling of fibres of the adjacent plexus, that it is impossible to stimulate one set of fibres without stimulating another, is, so far as I know, incapable of a definite answer at the present time.

It seems to me not improbable that this is a *genuine* reflex from the ganglia in the plexus. If it be true, as suggested by Sokownin and others, that the inferior mesenteric ganglion is capable of acting as a reflex centre for the bladder, then there seems to be no *a priori* reason why the ganglia on the branches of the pelvic plexus should not in like manner act as reflex centres for the bladder.

I am therefore inclined to the view that the ganglia on the pelvic plexus may act as reflex centres, in addition to being trophic and distributing centres.

The Pudic Nerve.

The Pudic, an ordinary skeletal nerve, which in the Dog practically corresponds to the internal pudic nerve of Man, is sensory to the second or genital portion of the urethra, namely, that part which extends from the prostate gland to the end of the penis, also to the skin of the penis and perinæum; motor to the sphincter ani, to the levator ani, which receives a small additional branch from the sacral plexus directly, to the external sphincter of Henle, and to the constrictor urethræ (these two last forming together one continuous sheet of muscle), to the accelerator urinæ, and to the other special muscles found at the root of the penis.

If the nerve be exposed on the outer surface of the levator ani, and stimulated in its continuity, the first result is contraction of all the muscles above mentioned. They contract in a particular order or sequence, namely, sphincter ani, levator ani, and then the muscles of the urethra and penis from behind forwards, the sphincter ani starting and the accelerator urinæ ending the sequence. Almost immediately afterwards there follow reflex

disturbances of the central nervous system, such as are obtained by stimulation of an ordinary sensory nerve—disturbances in the circulatory and in the respiratory systems, followed by disturbances of all the reflex centres of the spinal cord. If the nerve be divided and its peripheral end alone stimulated, the contraction of the muscles only occurs.

Hence, stimulation of the trunk of the pudic nerve induces contraction in what I have elsewhere (in Part I., *Journ. of Anat. and Phys.*) termed the *pelvic* group of striped muscles—a contraction which does not take place in all the muscles at one and the same time, but in regular sequence, the wave of contraction starting in the sphincter ani and ending in the accelerator urinæ in the male and in the striped muscle (external sphincter) of the urethra and special muscles of the clitoris in the female. Although each muscle may be induced to contract separately by stimulating the branch that supplies it, yet it is difficult, if not impossible, to cause voluntary contraction of any one of those muscles without contraction more or less complete of all the remainder. For example, when a person desires to cause contraction of the striped muscle around the urethra (constrictor urethræ), so as to suddenly check the outflow of urine, it will be found that the whole pelvic group contracts, the contraction starting with the sphincter ani. Again, if it be desired to cause firm closure of the anus, the contraction of the sphincter ani starts and is followed by the normal sequence which ends in the accelerator urinæ. Here, therefore, is a group of striped muscles which have acquired the habit of contracting in a particular order, namely, from behind forwards, so as to drive fluids outwards along the urethra. Thus, by a combined action of these muscles, the last drops of urine in the urethra are driven outwards, and so also is the seminal fluid which finds its way into the prostatic urethra.

If the trunk of the pudic nerve be divided and its central end alone stimulated, there occur, in addition to some obvious reflex disturbances in the central nervous system, certain interesting effects, clearly of a reflex nature, upon the bladder. If the bladder is in a quiet state there invariably occurs a slight reflex contraction of its walls, this being so small as to be invisible to the naked eye, but clearly observable by means of a water

manometer. It is perhaps remarkable that this contraction is so small, seeing how readily, at any rate in children, a reflex contraction of the bladder followed by the passage of urine is set up by exposing the genitals. This slightness of effect may possibly be due to the influence of the anæsthetics used (morphine and chloroform). If, however, the bladder wall is firm and in a state of tonicity, stimulation of the central end produces a transient contraction followed by a rapid and pronounced relaxation. This result is precisely the same as that which I have described above as resulting from stimulation of the peripheral end of the divided hypogastric nerve; with this difference, however, that in the case of the internal pudic nerve it is produced through the spinal (lumbar) cord, and in the case of the hypogastric it results either by direct action on the muscle wall of the bladder or, indirectly, through the ganglia on the pelvic plexus. This is, I presume, the same effect as Goltz, in his well-known experiments on the rectum, obtained in dogs by stimulating the central end of the sciatic nerve. May it not be that the common form of retention of urine after operations in the territory of the internal pudic nerve is really of this nature, that is to say, an effect of inhibition of the muscular wall of the bladder rather than an undue activity of the striped muscles of the urethra? To this interesting question I shall refer later.

SUMMARY.

Before leaving this subject it may be well to summarise briefly the chief results of stimulation of the nerves going to the bladder and to the urethra, as given in the preceding pages.

The Pelvic Splanchnics are the chief sensory and motor nerves to the bladder. The influence of each nerve is confined to the lateral half of the bladder on the same side. In consequence of this, it is necessary, in order to obtain a uniform contraction of the bladder, to stimulate both nerves, right and left, simultaneously. This simultaneous stimulation of the pelvic splanchnic nerves under ordinary circumstances is effected by a centre, probably bilateral, in the lumbo-sacral part of the spinal cord. Stimulation of the central end of one divided nerve produces reflex contraction of the lateral half of the

bladder on the opposite side, and also great disturbances of the central nervous system, which manifest themselves chiefly in inspiratory dyspnœa and general convulsive movements. Thus although the bladder is a median unpaired organ, yet each lateral half may contract independently of its fellow—the contraction having no tendency to spread over the median line to the opposite half in virtue of direct continuity of the muscular fibres. The effect of the stimulation of this nerve is not confined to the external longitudinal layer of muscle fibres as hitherto supposed, but is distributed to all the muscular fasciculi in that lateral half, whether they run longitudinally, circularly, or obliquely.

The *hypogastric* is a motor as well as a sensory nerve to the bladder. But in each of these respects it is feeble as compared with the pelvic splanchnic nerve. It is difficult to determine whether the effect of this nerve on the bladder is so limited as is that of the pelvic splanchnic on one or other lateral half, but it certainly resembles it in affecting the entire thickness of the muscular fibres, and not one layer only. In addition to being a sensory and motor nerve, it is capable of causing a marked and rapid relaxation of the muscular wall of the bladder when previously in a state of contraction or tonicity,—the greater the tonicity of the wall the more pronounced is the relaxation. This effect is obtained by stimulation of the *peripheral* end of the divided nerve. A similar effect can be obtained reflexly, by stimulating the *central* end of the divided trunk of the pudic nerve. Thus the same effect may be obtained directly or indirectly through the spinal cord.

Stimulation of the *branches* of the pelvic plexus gives the same result as stimulation of the trunk of the pelvic splanchnic. The direct influence of each branch is limited to the area it supplies. I am disposed to regard the ganglia of the pelvic plexus as capable of acting as reflex centres, just as the inferior mesenteric ganglion is said to be by Sokownin and others.

The *pudic* is motor to the sphincter ani, levator ani, and all the striped muscles of the urethra and of the penis in the male, and of the vagina and clitoris in the female; and sensory to the *second* or genital portion of the urethra, and to the skin of the penis and perineum. It is also capable of reflexly causing

marked and rapid relaxation of the bladder wall when in a contracted or tonic state. It is noteworthy that stimulation of the peripheral end of the trunk divided high up causes contraction of all the muscles above named in sequence, the sphincter ani starting and the accelerator urinæ ending the series; and also that when there is the voluntary desire to set one of these muscles in action, the whole group is involuntarily set in motion to accomplish the desired effect. This association has, no doubt, been developed in conjunction with the necessity of forcibly driving forward the contents of the urethra, and especially the seminal fluid.

(*To be continued.*)

AN ACCOUNT OF SOME RARE NERVE AND MUSCLE ANOMALIES, WITH REMARKS ON THEIR SIGNIFICANCE. By G. ELLIOT SMITH, M.B., Ch.M. (Syd.), *Demonstrator of Anatomy, University of Sydney, N.S.W.*

I. *Anomalous Condition of Brachial Plexus.*

IN a male subject recently dissected in the Practical Anatomy room of this University, and in which numerous muscle and nerve anomalies were noticed, the brachial plexus on both sides presented some marked peculiarities. During the dissection of the left axilla, a large lateral cutaneous branch was seen proceeding from the first intercostal space. This immediately divided into two branches, both of which were distributed along the inner aspect of the arm almost as far as the elbow. The upper of these, whilst in the axilla, gave off a small branch which ascended and joined a twig of about the same size from the internal anterior thoracic nerve, the conjoined nerve going to supply a pectoralis quartus slip, about half an inch wide, which formed the posterior or deeper part of the lower border of the pectoralis major, but was inclosed in a distinct sheath, and was inserted under cover of the pectoralis major. The intercosto-humeral nerve was of the ordinary size and divided into three branches, of which the uppermost was joined by a twig from the lateral cutaneous branch of the first dorsal. There was no nerve of Wrisberg.

A careful dissection was subsequently made of the right brachial plexus, which presented, among other rare anomalies, some hitherto undescribed. The arrangement is diagrammatically represented in the appended figure, p. 96. From the outer cord of the plexus the external anterior thoracic nerve (*e.a.t*) was given off in the ordinary manner, but it was connected with the internal anterior thoracic nerve (*i.a.t*) only by a very fine filament (*c*), not so large as the nerve which supplies the posterior belly of the omo-hyoid muscle. The external anterior thoracic nerve

divided into three branches of about equal size. The upper of these pierced the costo-coracoid membrane, and supplied the clavicular and the upper part of the sternal divisions of the pectoralis major. The second branch divided into two series of branches, of which some pierced the pectoralis minor, supplying its upper part, others turned round its upper border to reach the "gladiolar portion" of the pectoralis major. The third branch passed backwards (dorsally) and broke up into a large number of small branches, which ramified on the coats of the axillary artery in much the same way as branches of the anterior division of the obturator nerve—the nerve which supplies the muscles of the leg, homologous to those supplied by the external anterior thoracic in the arm—ramify on the femoral artery.

The internal anterior thoracic nerve arose in the ordinary way from the inner cord of the plexus and divided into two branches, the upper and larger of which, after giving off a fine twig of communication (c) to the external anterior thoracic, divided into a branch to the lower part of the pectoralis minor (p') and a branch (p'') to the lower border of the pectoralis minor and pectoralis quartus. The latter (p'') was joined (as on the other side of this subject) by a small twig (c'') which came from a very large lateral cutaneous branch of the first dorsal nerve (L.C). The second or smaller division of the internal anterior thoracic (W), after communicating by means of a small filament (c^{v}) with the lateral cutaneous branch of the first dorsal, was joined by a small twig (c^{iv}) from the intercosto-humeral, and was distributed in the region of the posterior axillary fold. This was the only representative of the nerve of Wrisberg.

The trunk formed by the junction of the anterior primary divisions of the eighth cervical and first dorsal nerves divided in the ordinary manner into ventral and dorsal divisions. The latter (L) divided into two branches—a branch which helped in the formation of the posterior cord of the plexus, and a second nerve (I.C′) which ran downwards in the axilla, lying just to the inner side of the internal cutaneous nerve (I.C), and associating itself with the ulnar nerve, descended as far as the space between the internal condyle and the olecranon, below which level it was distributed in the same manner as the posterior division of the internal cutaneous nerve is usually

distributed. The internal cutaneous nerve arose in the ordinary way, but its distribution was restricted to the area usually supplied by its anterior division.

A lateral cutaneous branch (L.C) of the first dorsal was also present on the right side, but was much bigger than on the left, being almost as large as the internal cutaneous. In the axilla it remained practically undivided, only giving off three very fine twigs. One of these (c') joined the fine loop (c) between the anterior thoracic nerves (c''), united with the branch (p'') of the internal anterior thoracic to the pectoralis major and pectoralis quartus, while a third (c^{iii}) formed a loop of communication (c^{v}) with the smaller division (W) of the internal anterior thoracic. The intercosto-humeral nerve (*i.c.h*) was very small.

Examining the condition of the first and second dorsal nerves inside the thorax, the following peculiar condition was found on the right side. The second nerve (DII) was found to give off a fairly large branch, which, proceeding upwards over the second rib, closely associated with the superior intercostal artery, divided into two branches. The larger of these (a), after joining a branch of the first dorsal nerve, recrossed the second rib to supply the muscles in the *second* intercostal space (b). On account of the previous disturbance of the part by dissection, I was unable to determine the connections of the second branch (a'), but it appeared to have joined the intercostal (lateral cutaneous) branch of the first dorsal. The latter, after giving off a small muscular branch (d) near the head of the first rib, was continued with this branch as far as the mid-axillary line, where it perforated the thoracic wall to enter the axilla.

The intrathoracic arrangement of the nerves on the left side presented nothing specially noteworthy, except the fact that there were two well marked communicating branches from the second dorsal nerve, which joined the first dorsal trunk *before* it divided into its brachial and intercostal portions.

From the posterior cord of the right brachial plexus four subscapular nerves sprung. Of these the first two (S^1 S^2) supplied the upper part of the subscapularis muscle, and represented the first subscapular nerve. The third (S^3) was the long subscapular. The fourth (S^4) arose alongside the circumflex, and, after giving

a few twigs to the subscapularis, supplied the teres major. In addition to these nerves the circumflex nerve (O), as it turned round the lower border of the subscapular muscle, gave four small twigs (O^1 O^2 O^3 O^4) to that muscle. This arrangement recalls the distribution of the subscapular nerves in a typical mammal (the Porcupine) as described by Paterson (I., *a*). Turner (II., p. 104) has recorded several cases in which the circumflex nerve has given twigs of supply to the subscapularis and teres major, in the absence of a branch from the subscapular nerves to the latter muscle. In the case here recorded, however, the latter branch was present, and the twigs from the circumflex all went to the subscapularis.

With reference to the interpretation of the conditions described, several features of the arrangement call for special remark. It will be noted that on the right side of the body the two anterior thoracic nerves were connected only by a very delicate filament. Practically no interchange of fibres can therefore have occurred in this case, and hence this arrangement of the nerves shows at a glance the morphological distribution of the fibres of each nerve. The arrangement agrees well with that recorded by Herringham as a result of his investigations (IV., p. 423). The external, derived from the fifth, sixth, and seventh cervical nerves, supplied not only the "anterior pectoral segment" of Windle (III.), but also a considerable portion of the "middle pectoral segment," including both its "gladiolar" and "costal" portions. Concerning the distribution of this (anterior pectoral) nerve, Windle says (III., p. 348) that it is quite definite and distinct both in its connections and distribution to the anterior pectoral segment. In the case here recorded, however, the external anterior thoracic nerve must include some branches which ordinarily form part of the middle pectoral (internal anterior thoracic) nerve. Regarding this nerve Windle (*loc. cit.*) says—

"Sometimes the greater part of this nerve appears to be derived from the outer trunk [of the plexus], sometimes from the inner, but the latter is by far the more common condition. . . . . . It corresponds to the internal anterior thoracic of human anatomy, which, arising from the inner trunk, receives also a constant and sometimes large branch of communication from the external or upper nerve coming from the outer trunk."

The double nerve supply of the dorsal, *i.e.* deeper, part of the lower border of the pectoralis major on both sides—from the internal anterior thoracic and the lateral cutaneous branch of the first dorsal nerve—helps to establish its identity as a pectoralis quartus. In a well developed example of pectoralis quartus in another subject, the insertion was blended with the insertion of a large achselbogen, which had a double nerve supply similar to the pectoralis quartus in this subject. The resemblance between and the frequent union of the insertions of the pectoralis quartus and achselbogen, together with the similarity of their nerve supply, seem to indicate that, whatever their homologies, they both belong to the same muscular sheet.

With regard to the internal cutaneous nerve, the condition here recorded is very remarkable, because if part of the nerve belongs (as it certainly does in this case) to the dorsal series of branches, the nerve, as ordinarily met with, will form another exception to Paterson's law "that, in the formation of the plexuses, the dorsal unite with dorsal and the ventral with ventral branches only." Paterson has himself pointed out an exception to his own law in the case of the small sciatic nerve, which he now regards as a mixed nerve, formed by the union of dorsal and ventral branches (V., p. 177). It is of interest to note in this connection that, like the small sciatic, the internal cutaneous nerve lies along the post-axial border of the limb. After meeting with the case here recorded, I examined the distribution of the internal cutaneous, the lesser internal cutaneous (Wrisberg), and intercosto-humeral nerves in several subjects. All of these subjects except one complied with the classical description, making due allowance for the variability of cutaneous nerves. In one subject, however, there was no intercosto-humeral nerve on either side, but a very large nerve of Wrisberg, which not only replaced the intercosto-humeral, but also invaded the territory usually supplied by the internal cutaneous, just below the internal condyle of the humerus. In the other subjects the size and area of distribution of the nerve of Wrisberg varied inversely with that of the posterior division of the internal cutaneous. It is now a well recognised fact, to which Cunningham (VI., p. 539) drew attention, that the intercosto-humeral nerve and the nerve of Wrisberg constitute alter-

native paths for the same series of nerve filaments. The facts recorded in this paper seem to point to the fact that additional paths for the same fibres are to be found in the lateral cutaneous branch of the first dorsal (when present) and the posterior division of the internal cutaneous nerves. Now, Paterson says (I., *a*, p. 154)—

> "The inferior [anterior primary] division of each nerve entering a limb plexus is homologous with the whole [anterior primary division] of the intercostal or anterior lumbar nerve, and that the dorsal and ventral divisions of the nerve in the plexus correspond respectively to the lateral and anterior or inferior branches of the intercostal nerve."

If this be true, not only does the nerve of Wrisberg, but also part of the internal cutaneous nerve—both usually springing from the *ventral* portion of the plexus—belong to the same series of branches as the intercosto-humeral, *i.e.*, to the series of dorsal branches; and the condition present in this subject, instead of being a mere abnormality, really reveals the true morphological arrangement of the plexus.

As regards the presence of a lateral cutaneous branch of the first dorsal nerve, Paterson's observations on the mammalian brachial plexus show that—

> "the first thoracic nerve always plays an important part by its axillary branch [in the formation of the brachial plexus, but] the remaining small portion, which is intercostal, never becomes cutaneous in the ventral line of the body, but ends in the muscles of the first intercostal space" (I., *b*, p. 630).

This nerve evidently takes the place (in the case here recorded) of the intercosto-humeral and the nerve of Wrisberg to a large extent. Now, the accumulated evidence, not only derived from anatomical but also from physiological and clinical research, localises the origin of both of these nerves largely, if not mainly, in the second dorsal segment of the spinal cord. If such be the case, we should expect to find a large bundle of fibres passing from the second to the first dorsal nerve, to convey the fibres of the lateral cutaneous branch of the first dorsal nerve. Such an arrangement exists on the left side, but on the right side there is a very different condition of affairs. A connecting

link certainly does exist, but of this the greater part (a) has no communication with the intercostal or brachial parts of the first dorsal nerve. We shall consider this branch later. The connections of the other (smaller) part (a') were not made out with certainty, but even if this joined the lateral cutaneous part of the first dorsal, as it seemed to do, it would be quite inadequate to carry all the fibres which passed out as the lateral cutaneous branch. The only other way of explaining the state of affairs is to assume that an intracentral passage of fibres takes place from the nucleus of the second intercostal nerve, some of whose fibres pass out with the first dorsal nerve. This view receives a strong support from the very peculiar distribution of the branch (y) of the first dorsal nerve. This branch is distributed to the muscles in the second intercostal space, thereby clearly showing that the branch (y) belongs morphologically to the second dorsal segment.

II. *Musculus pisi-uncinatus.*

A very well developed specimen of this rare muscle was found in the left hand of a very muscular labouring man.

The muscle was first described in 1866 by Calori (VIII., p. 140) as the "musculo piso-uncinato." It was next recorded by W. Gruber (VIII., p. 202) in 1875 under the name of "pisi-hamatus." The latter observer in 1880 systematically examined 200 subjects for this muscle and found it in 2·5 per cent. of these cases (IX.). In all he found twelve cases. Apart from these, the only other case I can find recorded is that of Calori. It is worthy of note that in all the cases in which the muscle was present on only one side it was the left, as in this case. In only one of the recorded cases was the muscle anything like the size of the muscle here recorded. The origin also is broader and slightly different from any of Gruber's cases. It formed a plump rounded mass on the anterior aspect of the annular ligament, but completely hidden by a very well developed palmaris brevis, from which it was separated by a small quantity of fatty tissue and the hypothenar fascia, as well as by the ulnar artery and the superficial division of the ulnar nerve, both of which took a

distinct curve outwards (radially) round the prominent fleshy belly to cross the thin expanded origin.

The muscle arose by an obliquely directed origin 17 mm. wide from the tendon of origin of a largely developed opponens minimi digiti, from the hook of the unciform bone, and from the lower border and anterior surface of the anterior annular ligament. From this origin a fleshy belly, 6 mm. thick and 3 cm. long, extended upwards and inwards to be inserted into the whole of the anterior and part of the internal surface of the pisiform bone, and into the anterior and inner surfaces of the tendon of the flexor carpi ulnaris. The deep branches of the ulnar nerve and artery sprang from the parent trunks fully 2 inches above the pisiform, and passed under cover of the muscle to enter the "canalis hamo-muscularis" (Gruber). The muscle was supplied by a twig from the deep branch of the ulnar, which entered the muscle just near its insertion to the pisiform bone.

III. *Double Nerve Supply to the Musculus gemellus superior.*

In a subject dissected for demonstration purposes, the nerve to the quadratus femoris, in addition to giving a twig to the inferior gemellus, also supplied a twig to the superior gemellus. The nerve to the obturator internus also gave a branch to the superior gemellus, so that the muscle had a double nerve supply. On dissecting the other side of the subject the same condition was found to be present.

In all English text-books the nerve to the quadratus femoris is described as supplying the inferior and not the superior gemellus muscle, but in Schwalbe's *Neurologie* (X., p. 963) it is described as supplying the two gemelli. I subsequently examined the distribution of this nerve in six other cases, in all of which it presented the arrangement described in English text-books.

This anomalous condition of the nerve to the quadratus femoris invading the territory of the nerve to the obturator internus is interesting in the light of comparative anatomy, presenting, as it does, an indication of the primitive arrangement of the nerves of supply to these muscles.

Professor Cunningham (XI., *a*, p. 143; *b*, p. 270) describes the "nerve to the quadratus femoris" supplying both gemelli as well as the adductor magnus in *Thylacine* and *Cuscus*. Professor Wilson has described the "nerve to the quadratus femoris" giving off the "nerve to the obturator internus" in *Dasyurus viverrinus*. In the same place (XII., p. 355) the same observer publishes a unique case in which the "nerve to the quadratus femoris" invades the territory of the great sciatic nerve after the marsupial type. In the present case we have an instance of an invasion in the other direction, an extension of the nerve towards the upper part of the great ischio-femoral mass revealing a tendency towards the condition existing in Dasyurus.

IV. *Musculus peroneus quartus.*

Well developed specimens of peronei quarti were found in both legs of a subject which presented numerous other commoner anomalies. On the left side the muscle arose by a large fleshy belly from the posterior aspect of the fibula between the peroneus brevis and the flexor hallucis muscles, with the former of which it was blended in its upper part. The strong tendon of insertion split into two parts, the larger of which was inserted into the floor of the groove on the outer surface of the os calcis through which the tendon of the peroneus longus passes. The smaller part was inserted partly into the posterior surface of the os calcis and partly into the deeper layer of the aponeurosis of the leg under cover of the tendo Achillis. In the right leg there was a peroneus quartus almost as large as that in the left leg, but inserted, like the larger division of the tendon, on the left side.

This muscle has been met with by Gruber in 13 per cent. of the subjects examined (XIV.). The name *peroneus quartus* was given to it by Otto (Neue Seltene Beobachtungen S. 40): Macalister (XV.) calls it *peroneus sextus*. Testut (XIII., p. 753) regards it as a *peroneo-calcaneus externus* variety of the musculus peroneus quinti digiti of Huxley. Testut describes how, in the series of mammals, the attachment of the latter muscle shifts backwards, or, as he puts it, gains "secondary" attachments, first to

the fifth metatarsal, then to the cuboid, the calcaneum, or even, in one instance, the external malleolus, constituting a whole series of muscles, which have been described under various names by different writers. The additional slip on the right side of this subject, inserted into the fascia of the leg, constitutes another stage in this retrogression.

(In this foot was a well marked instance of an *extensor primi internodii hallucis* tendon of Macalister, the fourth noticed in the last two weeks.)

V. *Other Uncommon Abnormalities.*

In the subject in which the anomalous brachial plexus described above was met with, the abductor minimi digiti of the right hand, in addition to its usual origin, had a broad fan-like origin from the deep fascia of the forearm about 2 inches above the wrist, from which it extended downwards across the ulnar artery and nerve to the radial side of the pisiform bone, where it joined the other portion of the muscle. At the site of this high origin the deep fascia of the forearm was strengthened by a strong accession of fibres from the tendon of the flexor carpi ulnaris. The muscle was supplied by a twig from the ulnar nerve. There was no palmaris longus —a fact which is interesting because Macalister (XV.) regards this muscle as a *palmaris accessorius.* A similar case is recorded by J. W. Smith (XVI.) and three cases by Wood (1868), but in none of these cases is there any mention of the peculiar connection of the tendon of the flexor carpi ulnaris with the high origin. In this connection may be mentioned a case met with in the class of operative surgery. In cutting down upon the ulnar nerve a dense thick aponeurotic layer, more than an inch wide, was found in front of the ulnar side of the carpus. On further examination, the flexor carpi ulnaris was found to be fleshy right down to its insertion, a slight aponeurotic band forming its radial border. About 3 inches above its insertion it gave rise to a strong fleshy belly, which almost immediately gave place to the strong fibrous band above mentioned, which expanded to form the palmar fascia. There was no other representative of a palmaris longus. The same condition was present to a lesser

degree on the other side, but was sufficiently well marked to confuse the operator.

In the arm containing the anomalous plexus (*supra*) the median nerve passed behind the brachial artery, and, as is usual in such cases (Turner, *loc. cit.*), the circumflex and profunda vessels arose by a common trunk. The biceps in the same arm arose by a broad aponeurotic sheet which extended from the coracoid process to the floor of the bicipital groove of the humerus. The representative of the upper part of the long tendon constituted a ligament attached distally to the upper extremity of the bicipital groove.

In another arm, the brachialis anticus muscle had a triple nerve supply—from the musculo-cutaneous, musculo-spiral, and median nerves. As the latter gave off a large communicating branch to the musculo-cutaneous nerve, the twig to the brachialis anticus muscle was in all probability merely part of the musculo-cutaneous fibres which were conveyed by the "median" path. On both sides of this subject the biceps had a humeral head, and the palmaris longus was represented merely by a fibrous band, and the flexor sublimis was connected with the flexor longus pollicis and flexor profundus digitorum tendons by means of two well developed muscles, whose nervous supply corresponded with the deep muscles to which they were attached. The lumbrical muscles presented a peculiar anomaly in the right hand. In addition to the usual muscles, all of which had bicipital origins, and one of them (the third) a bicipital insertion, there was present an additional muscle, which appeared in the middle of the forearm as a delicate rounded tendon to the outer side of the flexor sublimis digitorum, but which could be traced on the deep surface of the latter muscle as far as the internal condyle. This tendon at the upper border of the anterior annular ligament gave rise to a delicate muscular belly, which was inserted mainly into the index tendon of the flexor sublimis just opposite the metatarso-phalangeal joint, but partly also by a delicate slip into the dorsum of the finger, like an ordinary lumbrical. A slip somewhat similar to this has been described by Wilson (XVII.). In this case the flexor longus pollicis was inserted into the anterior annular ligament, a small part of the tendon giving rise to a muscle inserted like the one

in question. The flexor profundus digitorum gave off the tendon to the thumb.

In conclusion, I must express my deepest gratitude to Professor Wilson for the kindly advice which he has at all times willingly given me, both as regards methods of work and in the search for references.

[DIAGRAM.

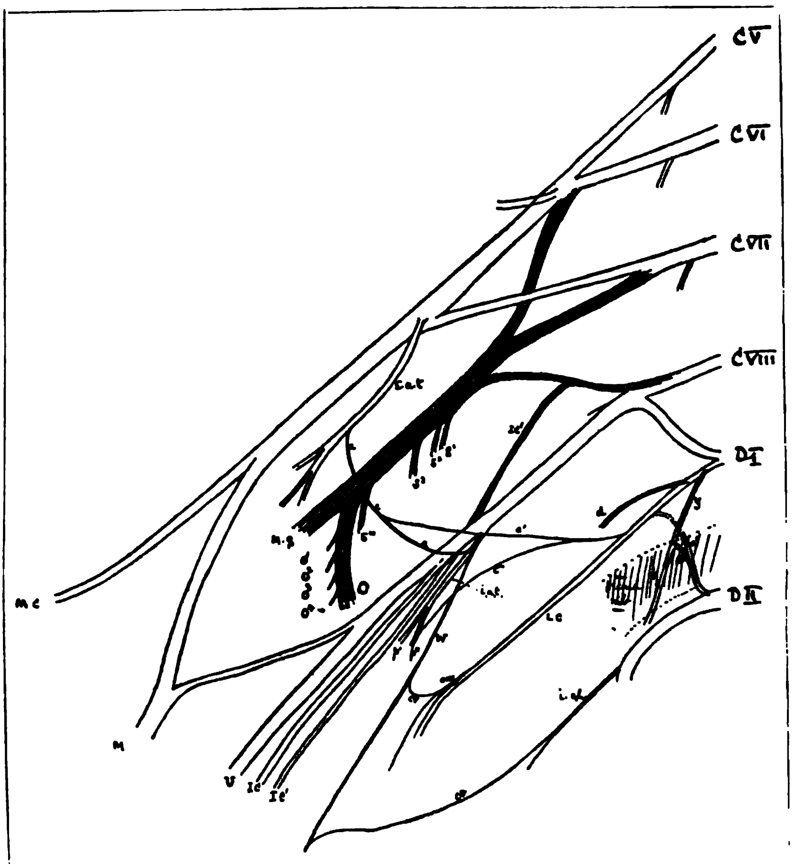


Diagram to Illustrate the Anomalous Brachial Plexus described in the text.

REFERENCES TO THE DIAGRAM.

e.a.t, external anterior thoracic.
i.a.t, internal anterior thoracic.
c, their delicate loop of intercommunication.
d, the intercostal branch of the first dorsal.
L.C, its large lateral cutaneous branch.
p', branch of *i.a.t* to the pectoralis minor.
p'', branch of *i.a.t* to the pectoralis major and quartus.
w, the smallest branch (cutaneous) of the *i.a.t.*
c', a delicate communicating filament from the first dorsal to the loop of communication, *c*.
c'', a twig from the lateral cutaneous division of first dorsal to *p''*, the branch of *i.a.t* to the pectoralis quartus.
*c*iii, a communicating twig between *w* and L.C.
i.c.h, intercosto-humeral nerve.
*c*iv, a loop of communication between *i.c.h* and *w*.
$s_1\,s_2$, the representatives of the first subscapular nerve.
s_3, the long subscapular.
s_4, subscapular nerve supplying teres major.
O, circumflex nerve.
$o^1\,o^2\,o^3\,o^4$, twigs from *O*, to the lower border of the subscapular muscle.
M.C, musculo-cutaneous.
M.S, musculo-spiral.
M, median.
U, ulnar.
I.C, internal cutaneous.
I.C', posterior division of internal cutaneous, arising in common with one of the roots of origin of the posterior cord of the plexus.
a.a', branches of communication passing upwards across the second rib.
b, nerve crossing second rib to supply the muscles in the second intercostal space.

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NOTE ON A PECULIAR ARRANGEMENT OF THE SUPRA-SCAPULAR VEIN. By G. Elliot Smith, M.B., Ch.M. (Syd.). *Demonstrator of Anatomy, University of Sydney, N.S.W.*

In a subject which presented a large number of anomalies, the most noteworthy of which have been communicated to this Journal in the previous paper on "Some rare Nerve and Muscle Anomalies," there was present a very peculiar condition of the veins in the left axilla.

The suprascapular artery arose from the first part of the axillary artery, a variety mentioned in *Quain's Anatomy*. The corresponding vein ran downwards parallel to the artery, and at the inner side of the axillary artery changed its direction and ran parallel to the cords of the brachial plexus to join the subscapular vein by two roots, so that with the subscapular trunk it formed a vascular ring. The subscapular vein received veins corresponding to the circumflex and profunda arteries, and was placed very low,—in fact, outside the axilla proper. The long subscapular nerve was directed downwards in the axilla parallel to the suprascapular vein and the inner branches of the brachial plexus, beyond the lower fold of the axilla, where it took a bend at right angles, passing through the vascular loop as through a pulley.

Quain (10th edition, vol. ii. pt. ii. p. 425) says the supra-scapular artery "has been found to proceed from the axillary artery, and from the subscapular branch of that vessel." In this case the artery belonged to the first variety here mentioned, while the vein corresponded to an artery belonging to the second variety.

HISTOLOGICAL CHANGES INDUCED IN SYMPATHETIC, MOTOR, AND SENSORY NERVE CELLS BY FUNCTIONAL ACTIVITY. (*Preliminary Note.*) By GUSTAV MANN, M.D., *Assistant to the Professor of Physiology, University, Edinburgh.* (PLATE I.)

(Read before the Scottish Microscopical Society, May 18th, 1894, under the title: "What alterations are produced in nerve cells by work?")

WITHIN the last few years several endeavours have been made to determine whether the functional activity of the nervous system is accompanied by demonstrable histological changes in nerve cells, and the respective investigations have resulted in a confirmation of the surmise.

The chief observations were made by F. C. Hodge [1] in America, who stimulated with an induced current the intervertebral ganglia on the posterior roots of spinal nerves, and who, in addition, also studied the phenomena of daily fatigue by comparing the cephalic ganglia of bees, swallows, &c., which had been placed in fixing solutions in the morning, after a night's rest, with those fixed in the evening after a day's labour. The changes he observed in nerve cells stimulated faradically, fixed and stained in 1 per cent. osmic acid, are these:—In the resting nerve cell the nucleus is paler than the protoplasm, and it possesses a smooth outline, while in the fatigued cell the nucleus is darker than the protoplasm, crenated, and markedly decreased in size. The protoplasm of the fatigued cell shows a slight shrinkage in size;—lessened power to stain or to reduce osmic acid and vacuolation. In the cell capsule he further noticed a decrease in size of the nuclei.

[1] C. F. Hodge, (*a*) "Some effects of stimulating ganglion cells" (Prelim. Comm.), *Amer. Journ. Psych.*, vol. i. p. 479, 1888, Baltimore; (*b*) "Some effects of electrically stimulating ganglion cells" (Dissertation), *Amer. Journ. Psych.*, vol. ii. p. 376, 1889; (*c*) "The process of recovery from the fatigue occasioned by the electrical stimulation of ganglion cells," *ibid.*, vol. iii. p. 530, 1891, Worcester; (*d*) "A microscopical study of changes due to functional activity in nerve-cells," *Journ. of Morphol.*, vol. vii., 1892, November, No. 2, p. 1 [(*e*) "Die Nervenzelle bei der Geburt und beim Tode an Alterschwache, *Anat. Anzeiger*, vol. ix. No. 23, 1st August 1894, pp. 706–710. This reference has been added since the paper was read.—G. M.]

In his most recent communication (footnote 1, *e*) Hodge has compared ganglion cells of newly-born animals with those taken from very old animals (man and bee), and finds in advanced age (92 years) that the nucleoli of the spinal ganglionic cells are not stained with osmic acid, while they readily stain in newly-born infants. With age the nucleus becomes shrivelled, but does not stain more deeply than the protoplasm, as it does in the case of fatigue;—the protoplasm of the cell becomes pigmented [an observation I can fully confirm.—G. M.] and vacuolated. He noticed also that in the human cerebellum and in the cerebral ganglia of bees there goes hand in hand with advancing age a destruction of nerve cells amounting to 25 per cent. and more of the original number.

Friedrich Vas[1] then experimented on the superior cervical sympathetic ganglion of the rabbit. He stimulated the sympathetic nerve on one side of the animal, 3 cm. below the ganglion, for 15 minutes; the ganglion on the other side serving as a control.

Vas found in the stimulated ganglion an increase in the size of both the cells and their nuclei, and stated that the chromatin granules which surround the nucleus of the resting cell move in the stimulated ganglion to the periphery of the cell, and that thus a clearing of the central part of the cell is brought about. He did not suggest that the amount of chromatin diminishes during the activity of the cell. He further states that the nuclei go to the periphery of the cell.

The experiments of Vas were repeated by Lambert[2] on rabbits and cats, and the changes in the chromatin interpreted in the same way, but the French observer failed to make out an undoubted increase in size of the cells or air nuclei.

The great difference between the statements of the above observers, Hodge and Vas, necessitated further observations, and I therefore commenced my inquiry by repeating the experiments of Vas. The superior cervical sympathetic ganglia of rabbits

[1] Friedrich Vas, "Studien über d. Bau d. Chromatins in d. sympathischen Ganglienzelle" (1 pl.), *Arch. f. mik. Anat.*, vol. 40, 1892, Heft 3, pp. 375–389.

[2] Lambert, "Note sur les modifications produites par l'excitations électrique dans les cellules nerveuses des ganglion sympathiques" (Note prélim.), *Compt. rend. hebd. des séances de la Soc. de Biol.*, 1893, No. 31, Neuvieme série, Tome 5, pp. 879–881 (November).

and cats were fixed in various osmic acid mixtures, but preferably in my watery fixative, viz. :—

Saturated solution of $HgCl_2$ in ¾ per cent. NaCl	= 100 cc.
Picric acid, ...	1 gr.
Tannin, ...	1 „

or simply in a saturated solution of $HgCl_2$ in ¾ per cent. NaCl. As stains I used Toluidin blue, Ehrlich's Sulphuric acid Methylen blue, Methyl blue, and water-soluble Eosin, all obtained from Dr Grübler. Bordeaux red, Safranin, Congo red, Gentianviolet, and Methylviolet; Bismarck brown and Tropaeolin; Ehrlich's triacid mixture and Ehrlich-Biondi's fluid; M. Heidenhain's iron-alum-hæmatoxylin, Ehrlich's acid hæmatoxylin, and Delafield's hæmatoxylin.

The Methyl-blue I employ as follows :—

The ganglia should be fixed in $HgCl_2$, be taken through the paraffin process and sections be cut not thicker than 2½ μ.

The sections are fixed to the slide by my albumen method[1] and then placed, after the paraffin has been removed, in the following staining solution :—

1 per cent. Methyl-blue (Grübler), water soluble, and almost quite insoluble in Alc. absol. . .	= 35 cc.
1 per cent. Eosine, water soluble (Grübler), .	45 cc.
Aq. distill., ...	100 cc.

(1) Stain for 24 hours. (2) Remove superfluous stain with water. (3) Dehydrate with Alc. absol.

(4) Place slide in a glass vessel containing Alc. absol. = 30 cc.
1 per cent. NaOH in Alc. absol., . . 4 drops.

(5) Leave in this mixture till the dark blue section has become reddish (1–5 minutes).

(6) Wash off all traces of caustic soda with Alc. absol.

(7) Place sections into a vessel with tap water; bluish-red clouds will be given off. When no more clouds are given off, (8) transfer slide to a vessel containing water which has been acidulated with 2–3 drops of Acetic acid. Leave section in this water for 3 minutes to neutralise all traces of NaOH, to fix the Eosine and to deepen the

[1] Gustav Mann, *Anat. Anzeig.*, Jahrg. viii. (1893), p. 442.

Methyl-blue in colour. (9) Dehydrate with Alc. absol. and mount in Turpentine-balsam. If sections are still too blue the process will have to be repeated. In properly stained sections, the red blood corpuscles should be red, everything else blue with the exception of the nucleoli which are red or purplish. This method is the best I know of for the nuclear chromatin of nerve cells.

Sections of the ganglia were varied in thickness from $\frac{1}{2}$ to 8 μ, and fixed to the slides by my albumen method.[1]

A sympathetic nerve cell has a very complicated structure (figs. 1, 2); it is multipolar, and in the rabbit possesses, as a rule, two nuclei, although one to four may be found. The protoplasm of the cell consists of a ground substance with a great number of fibrils embedded in it, which run in bundles, and may be traced from one process past the nucleus into another process. *In no case do the nerve-fibrils spring from the nucleus.* Lying between the fibrils (fig. 10), I have been able to demonstrate by the above Methyl-blue and Eosine staining method, bodies which show characteristic staining reactions, and which up till now have not been described. Each of these bodies (there are four to ten in one cell) consists of two dumb-bell shaped elements placed side by side, and may therefore be called a "*bigeminal body*," and it is of such size as to be readily recognised when magnified 300 times.

Embedded in the ground-substance (" interfibrillar substance "), figs. 1 and 2, and lying most abundantly between the bundles of fibrils and at the very periphery of the cell, are numerous short rod-shaped chromatin granules, which were first described by Vas. It is these granules which Vas believes to move to the periphery of the cell after 15 minutes' electrical stimulation of the ganglion.

A repetition of Vas' experiments has shown me that an increase in the size of the ganglion cells and their nuclei does take place, but I could not convince myself of a shifting of the granules from the centre towards the periphery of the cell. The centre of the cell certainly becomes clearer (compare figs. 1 and 2), but this is due, firstly, to absorption of lymph by the central part of

[1] Gustav Mann, *Anat. Anzeig.*, Jahrg. viii. (1893), p. 441.

the cell, and secondly, due to either a change in the composition of the stainable material, rendering it unstainable, or to the using up of the chromatin rods.

The changes in the nucleus are these: In the resting nucleus the nuclear hyaloplasm is stained by my Methyl-blue eosin method, while it remains quite colourless in the stimulated cells. The true nuclear chromatin, which shows a specific affinity for Methyl green OO, is slightly diminished, and not increased as stated by Vas.

The nucleolus also enlarges and the endo-nucleolus becomes more evident, thus rendering the nucleolus paler. The linin threads are now readily recognised.

A further difference between the stimulated and control ganglion, best seen under a low magnifying power, is the following:—In the control ganglion the lymph spaces around the cells appear as clear lines, while the stimulated ganglion has a homogeneous look, for the spaces have disappeared because of the increase in size of the ganglion cells.

On stimulating a ganglion intermittently for 6–9 hours a further change may be observed (fig. 3):—The nuclei begin to darken slightly and to shrivel; this collapse being frequently restricted to one side of the nucleus. The chromatin rods of Vas are greatly diminished in number and very pale, while the "bigeminal bodies" are deeply stained, and stand out sharply.

The extreme stages of fatigue, as described by Hodge, namely, the nucleus becoming darker than the cell, I was unable to obtain.

So far, then, my results were not a simple confirmation of those obtained by Vas, for I found that the chromatin of the cell does not shift its position during activity, and that it actually undergoes diminution.

Starting with this idea, I passed to other portions of the nervous system, to see whether or not analogous changes could be found after ordinary normal stimulation.

On comparing the motor areas in the cerebra of two dogs, one of which had been resting, while the other had been doing ten hours' muscular work, I found the following changes:—

In the large pyramidal cells of the resting brain, fixed by injecting a warm saturated solution of $HgCl_2$ in $\frac{3}{4}$ per cent.

NaCl solution from the aorta, and stained for 5 minutes in a ½ per cent. watery solution of Toluidin-blue; then rapidly dehydrated in Alc. absol.; cleared in xylol; and mounted in turpentine balsam,—Nissl's chromatic spindles lying between the nerve fibrils are intensely stained. The interfibrillar ground-substance may also be deeply stained by the above detailed method of using Methyl-blue.

In the worked brain Nissl's spindles are less deeply stained by Toluidin blue; they may show a jagged outline, or may be altogether absent, while also the interfibrillar substance can no longer be stained with Methyl-blue.

Hence in the fresh brain the nerve cells appear as deep blue bodies on a light background, while in the worked brain they are very pale or quite colourless, and appear as light figures on a darker background.

The nuclei of the worked cells were swollen and the nuclear hyaloplasm colourless, the latter in the resting brain being distinctly stained with Methyl-blue.

In the lumbar region of the *spinal cord* (figs. 4, 5) in the fresh dog, the nuclei of the motor cells were paler or of the same intensity of colour as the protoplasm, with distinct separate chromatin granules, and the outline of the nucleus smooth, while in the fatigued dog the nucleus was darker than the protoplasm, stained homogeneously and distinctly shrivelled.

Hence the appearance first described by Hodge in the spinal ganglia, as resulting from prolonged electrical stimulation, can be confirmed as occurring normally as the result of excessive fatigue.

Nissl's spindles were further much less deeply stained and fewer in the fatigued cord as compared with the resting one.

Seeing the above marked changes in motor cells, the question naturally suggested itself to me, Can similar changes be seen in sensory cells? The special sense which I have investigated up till now is that of vision, and the effects of light on the retina and the optic centres of the brain are the following:—In four dogs (figs. 6, 7) which were allowed to run about for twelve hours with one eye covered up while the other eye was exposed, and the brains and retinæ of which were fixed by inject-

ing $HgCl_2$ from the aorta, I notice in the retina kept in darkness (fig. 6) that the nuclei of the rods are very rich in chromatin, the individual chromatin segments being globular, spherical externally, and facetted where in contact with one another, while in the exposed eye the chromatin segments are greatly shrunken and quite stellate. The nuclei of the ganglion cells of the dark retina are smaller than those in the exposed one, and in the latter the nuclear hyaloplasm is no longer stained with Methyl-blue.

In the nuclei of the external geniculate bodies, the corpora quadrigemina and occipital lobes (figs. 8, 9) corresponding to the dark eye, the ganglion cells are much richer in chromatin and the nuclei smaller than in those cells in connection with the exposed eye. In the Rabbit I have found the same changes, not so well marked in the retina, but more evident than in the case of the Dog on the lower aspect of the occipital lobe, but the investigation of the optic centres is not as yet completed. I hope, however, to be able to exactly localise the vision-areas in the case of the Rabbit, Dog, and Monkey by observing the changes the brain undergoes when stimulated by light.

In figs. 8, 9 there will be seen in several of the nuclei of the large pyramidal cells, peculiar deeply stained crescentic bodies, which may be the homologues of the centrosomes to be found in the nuclei of sympathetic nerve cells (compare fig. 1_7).

Another point worth mentioning is this. The cell chromatin to disappear last lies in many cases at that pole of the nucleus pointing towards the molecular layer, and there forms a distinct cap or pyramid. The reason for this being that the bundles of nerve fibrils coming from the basal processes and the axis-cylinder process have to sweep past the nucleus, that they converge only a considerable distance above the nucleus, and thus leave immediately above the nucleus an area free of fibrils, which is made use of for the deposition of food in the form of chromatic material.

My investigation has thus shown—

1. That DURING REST, several chromatic materials are stored up in the nerve cell, and that these materials are used up by it during the performance of its function.

2. That ACTIVITY is accompanied by an increase in size of the cells, the nuclei, and the nucleoli of sympathetic, ordinary motor and sensory ganglion cells.

3. That FATIGUE of the nerve cell is accompanied by shrivelling of the nucleus and probably also of the cell, and by the formation of a diffuse chromatic material in the nucleus.

In this preliminary note I feel indisposed to venture any speculation in explanation of the phenomena observed, but I shall endeavour to do so when my completed paper, accompanied by photographic illustrations, tables of measurements, and a fuller account of the literature, will make its appearance.

In conclusion, I have to express my deep obligation to Professors Rutherford and Munk, in whose laboratories the above researches were conducted.

DESCRIPTION OF PLATE I.

Figs. 1–3. Three cells from superior cervical sympathetic ganglion of the rabbit.

Figs. 1 and 2 fixed in my watery picro-corrosive fluid. Stained in Sulphuric acid Methylen-blue and Eosin.

Fig. 1. From the control ganglion, showing a resting nerve-cell, with (1) peripheral, (2) interfibrillar, (3) intrafibrillar chromatin rods, (4) the nuclear chromatin, (5) the nuclear hyaloplasm, (6) the nucleolus, with its endo-nucleolus, (7) centrosomes (?) lying in the nucleus.

Fig. 2. Cell from ganglion stimulated faradically for thirty minutes, showing diminution in the amount of chromatin, aggregation of lymph in the centre of the cell, &c.; (8) the enlarged nucleolus and endo-nucleolus, with delicate radiating fibrils of linin.

Fig. 3. Cell from ganglion stimulated nine hours. Fixed in equal parts of a saturated solution of $HgCl_2$ and 1 per cent. Osmic acid solution. Both nuclei collapsed and somewhat deeply stained.

Figs. 4 and 5. Two motor cells from lumbar region of spinal cord of dog. Fixed in $HgCl_2$, and stained in Toluidin blue. Fig. 4 from the fresh dog—(1) pale nucleus, (2) dark Nissl's spindles, (3) bundles of nerve-fibrils.

Fig. 5. From the fatigued dog, with (4) dark shrivelled nucleus and (5) pale spindles.

Figs. 6 and 7. V.S, retinæ of dog fixed in corrosive sublimate, stained in Toluidin-blue. (*a*) layer of nuclei of cones (1) and rods (2), (*b*) middle ganglionic layer.

Fig. 6 from eye kept dark.

Fig. 7 from eye exposed for twelve hours to ordinary daylight on a sunny day.

Figs. 8 and 9. V.S, from lower aspect of occipital lobe of rabbit. Fixed in sublimate, stained in 1 per cent. watery solution of Eosin for 1 minute and Toluidin-blue $\frac{1}{2}$ per cent. for 15 minutes. After treatment as stated above, p. 105. a = molecular layer; b = layer of cells, first described by Ramon y Cajal, for which I suggest the name "submolecular"; c = layer of small pyramidal cells; d = layer of large pyramidal cells. 1. Intra-nuclear chromatic crescents (centrosomes ?). 2. Chromatic material on apex of nucleus.

Fig. 8 corresponds to eye kept dark.

Fig. 9 corresponds to eye exposed for two hours to flashes of light.

Fig. 10. A sympathetic nerve-cell stained with Eosin Methyl-blue to show (1) nuclear hyaloplasm, (2) nuclear chromatin, (3) centrosomes (?), (4) nucleolus with endo-nucleolus, (5) five "bigeminal" bodies.

ARE THE EXTRINSIC MUSCLES OF THE AIR-BLADDER IN SOME SILUROIDÆ AND THE "ELASTIC SPRING" APPARATUS OF OTHERS SUBORDINATE TO THE VOLUNTARY PRODUCTION OF SOUNDS? WHAT IS, ACCORDING TO OUR PRESENT KNOWLEDGE, THE FUNCTION OF THE WEBERIAN OSSICLES? A CONTRIBUTION TO THE BIOLOGY OF FISHES.

By WILLIAM SÖRENSEN, Copenhagen.

Τῶν πόνων πωλοῦσιν ἡμῖν πάντα τ'αγάθ οἱ θεοί.

(Επίχαρμος.)

HAVING seen from a memoir by Professors Bridge and Haddon, in the *Proceedings of the Royal Society*[1] (*Ia*1), which was evidently the preliminary of a more extensive work, that these naturalists were engaged in studies of the anatomy of the Siluroidæ, and especially with that of the air-bladder and the modified vertebræ of these fishes, I took the liberty to forward, on February 9, 1891, to each of the said gentlemen a copy of two of my papers. I had treated in the former[2] of these papers the sound-producing organs in fishes; in the latter[3] the morphology of certain parts of the skeleton of fishes. In the former the Siluroidæ had precisely been the fishes from which I started my investigations. In the latter the conditions in the Siluroidæ, as the title of the paper shows, had been the principal object of my studies.

[1] *Ia*1 : Bridge, T. W., and Haddon, A. C., "Contributions to the Anatomy of Fishes. I. The Air-Bladder and Weberian Ossicles in the Siluridæ" (*Proc. Roy. Soc. Lond.*, xlvi., 1890, No. 283, pp. 309–328). *Ia*2: Bridge, J. W., and Haddon, A. C., "Contributions to the Anatomy of Fishes. II. The Air-Bladder and Weberian Ossicles in the Siluroid Fishes" (*Ibid.*, vol. lii., 1892, pp. 139–157.) The latter of these two papers I have read since the first sheet of this memoir of mine was in print.

[2] II*b* : Sörensen, William, *Om Lydorganer hos Fiske: En physiologisk og comparativ-anatomisk Undersögelse.* [On Sound-producing Organs in Fishes: A physiological and comparative anatomical examination.] Kjöbenhavn, 1884.

[3] III : Sörensen, William, *Om Forbeninger i Svömmeblæren, Pleura og Aortas Væg og Sammensmeltning deraf med Hvirvelsöjlen særlig hos Siluroiderne, samt de saakaldte Weberske Knoglers Morphologi.* [On Ossifications of the Air-Bladder, the Pleura, and the Wall of the Aorta, and their Fusion with the Vertebral Column, especially in the Siluroidæ, together with the Morphology of the so-called Weberian Ossicles.] *Avec un résumé en Français.* (*Danske Vidensk. Selsk. Skr.* 6 *R. Nat.-math.* Cl. Bd. vi. 2, Kjöbenhavn, 1890, pp. 67–152.)

Last summer Professors Bridge and Haddon published a voluminous work,[1] containing their anatomical studies of the Siluroidæ, a work which, on account of the evident diligence and ability displayed, as well as from the great number of fishes treated, will be for a long period a most important work in the anatomy of the organs in question.

Dr. Lütken, Professor of Zoology at the University of Copenhagen, has been so kind as to lend me his copy of this work, and I have thus been fortunate to make myself acquainted with its contents a long while before I should otherwise have been able to do so. It has been a great satisfaction to me to see that these two naturalists agree with me as to the morphological interpretation of the skeletal parts, as well in their morphological summary (pp. 224–261), as now and again in the special description of the fishes, and that they share the opinions I have suggested in my last work, of which they have evidently perused the "resumé en français." Nowhere, as far as I can see, have they urged any objections to the views I have set forth. However, I take the liberty to remark that the reports they have made of this paper of mine are not quite reliable,—a circumstance which is evidently due to their difficulty in interpreting the Danish language, nearly related though it be with the English. Thus they relate (p. 260) that I consider the "claustrum" as the neural spine of the first vertebra; the "stapes" (scaphium, Br. and Hadd.) as the neural arch of the first vertebra; the "incus" (intercalarium, Br. and Hadd.) as the neural arch of the second vertebra; the "malleus" (tripus, Br. and Hadd.) as the rib of the third vertebra. But such is not exactly my opinion of these skeletal parts. As to the "claustrum," on the contrary, I have been careful not to call it a neural spine, and I have shown that at the first 3 or 4 vertebræ in the Ostariophyseæ[2] (in other Physostomi only at

[1] *Ib:* Bridge, T. W., and Haddon, A. C., "Contributions to the Anatomy of Fishes. II. The Air-Bladder and Weberian Ossicles in the Siluroid Fishes" (*Phil. Trans. Roy. Soc. Lond.*, vol. clxxxiv., 1893, B., pp. 65–333).

[2] The name given to all families furnished with the Weberian ossicles by Sagemehl (p. 22). [IV: Sagemehl, M., "Beiträge zur vergleichenden Anatomie der Fische. III. Das Cranium der Characiniden nebst allgemeinen Bemerkungen über die mit einem Weberschen Apparat versehenen Physostomen-Familien" (in *Morphol. Jahrbuch.* x., Leipzig, 1885, pp. 1–119). With great force Sagemehl (*ib.*, p. 9) denies the existence of the Weberian ossicles in the Gymnarchidæ, which Bridge and Haddon count among the Ostariophyseæ. I have not examined the *Gymnarchus niloticus*.]

the first vertebra) there exists a separate ossicle, which sometimes forms part, sometimes not, of the spinal canal, and which, as far as I can judge, is homologous with the ossa imparia in the Acipenser.

After having mentioned the Weberian ossicles in each of the families belonging to the Ostariophyseæ, I have, to facilitate the survey, compiled the following table (III. p. 105):—

	Characini.	Cyprinoidei.	Cobitini.	Gymnotini.	Siluroidæ.
Claustrum.	The os commissurale of the 1st vertebra.			Is wanting.	The os commissurale of the 1st vertebra is often wanting.
Stapes.	The neural arch of the 1st vertebra.				
Incus.	The neural arch of the 2nd vertebra + ossified ligament.		Only ossified ligament.		
Malleus.	The rib of the 3rd vertebra + the basal part[1] of the rib + ossified air-bladder + ossified ligament.	The rib of the 3rd vertebra + ossified air-bladder + ossified ligament.			In Clarias and Plecostomus the rib of the 3rd vertebra + ossified air-bladder + ossified ligament. In the other genera [known to me] the rib of the 3rd vertebra + the basal part[1] of the rib + ossified air-bladder + ossified ligament.
Os suspensorium mihi [sc. vesicæ natatoriæ].	The basal part[1] of the rib of the 4th vertebra + ossified air-bladder.				Shares this function with other bones.

To whosoever has read, and were it only this table, it will be quite evident that my views as to the morphology of these

[1] Or the processus transversus.

ossicles are recorded by Professors Bridge and Haddon in a very superficial manner.

In all the (nine) genera of the Siluroidæ which I have examined, the "incus" in full-grown specimens consists of ossified ligament; but Bridge and Haddon have made the very interesting discovery that this ossicle forms a smaller or larger part of the neural canal in some genera (*e.g.*, Macrones, Liocassis, Pseudobagrus, Bagroides—Cryptopterus, Callichrous), in which respect these genera approach to the other families of the Ostariophyseæ.

When, however, Bridge and Haddon say (*Ib*, p. 261):—

> "A further question arises as to whether, in addition to a modified neural arch, the intercalarium [incus, Web.] did not originally include an element comparable to a transverse process. We are inclined to think that it did, and that the horizontal process of the ossicle, when present, represents the modified transverse process of the second vertebra. In its origin from the neural arch or ascending process, the horizontal process conforms precisely to the contiguous transverse processes of the fourth and fifth vertebræ, which spring in exactly the same way from the neural arches, and not from the centra of their respective vertebræ."

I may answer this question in the negative, because in fact I have already done so—a circumstance which, however, the authors had not observed, as they had not made themselves acquainted with the *Danish* part of my paper in question, in which is set forth the documentation of my morphological views. 1°. In the other families of the Ostariophyseæ, at the 2nd vertebra, there exists, besides the "incus" when present, a real[1] transverse process; nay, in the Gymnotini this process even carries a rib. 2°. A transverse process (or rib) in fishes always springs from the centrum of the vertebra, and never from the neural arch; when it seems to do so, it is only so in appearance. And to abide by the Siluroidæ, one glance at the figure (*Tb.* I. fig. 10) which I have given of this part of the vertebral column in the fœtus of *Galeichthys feliceps* also proves how the transverse processes of the (real) 4th and 5th vertebræ spring from the centra of their respective vertebræ, while the proximal end of the "incus" is fixed in the wall of the neural channel. And, starting from this fœtus, I have proved (III. pp. 101, 102) that

[1] I must add this designation, as on the 1st vertebra in the Cyprinoidei there exists a transverse process, which is false.

when the transverse processes of the normal vertebræ in the Siluroidæ *seem* to spring both from the centrum and the arch of their vertebra, this is due to a later ossification of the ligaments which—as in other fishes—unite the transverse processes (or ribs) with the neural arch. And I may add that when the modified transverse processes of the (real) 4th and 5th vertebræ seem to spring from the neural arches, this is equally due to a secondary transformation during the growth (in the very young animal), as briefly intimated in my paper (pp. 103–105). The "horizontal process" of the "incus" is ossified ligament.

Professors Bridge and Haddon say (*Ib*, p. 249), that in Clarias "the inferior limb" of the "post-temporal" "becomes quite rudimentary, and loses its usual articulation with the basi-occipital." On the contrary, I have declared that this "inferior limb" does not exist at all in this genus. This might seem but a very slight difference. To be sure, the difference of expression is very slight, but the difference as to the interpretation of the fact in question is anything but slight. For, as I have shown,—a fact also mentioned by Bridge and Haddon,—this "inferior limb" is a very essential point of the skeletal structure of the Siluroidæ. But what is this "inferior limb"? In most of the Teleostean Fishes the "pectoral girdle"—as is well-known — consists of three bones, called by Cuvier the "suprascapula," the "scapula," and the "humerus." As is equally well known, the uppermost of these bones is, as a rule, joined with two bones of the skull, viz., with the os squamosum (or temporale), and with the epioticum (or paroccipitale). The bone in the middle, in the Siluroidæ coalesced with the uppermost one to form the "suprascapula" (Cuvier), or the "post-temporal" (Br. and Hadd.), is—a fact[1] less well known—in most Fishes, also in Amia and Polypterus, united, as a rule,

[1] For this reason I have had the ligament drawn in all the figures I have published, where it was possible to do so. The only author who has mentioned it is, as far as I know, Mettenheimer, C., *Disquisitiones Anatomico-comparativæ de membro piscium pectorali*, Berolini, 1847. This ligament is also ossified in Dactylopterus (where it acts the same part as in the Siluroidæ), Aulostoma, and Ostracion (but not in Batrachus tau). This also appears to be the case in Lepidosiren, Protopterus, and Ceratodus. But as I have dissected none of these genera, I dare not state with certitude that the bone ("the first rib," Günther) which unites the first vertebra or the basis-cranii with the "shoulder-girdle" is homologous with the said ligament.

with the occipitale basilare, or uncommonly, as in the Cyprinoidei and the Gadoidæ, with the centrum of the 1st vertebra. But while the junction between the "suprascapula" and the epioticum is brought about by means of a slender process of the suprascapula — *i.e.*, an ossified ligament — in most cases the junction between the lower end of the scapula and the occipitale basilare, or the centrum of the 1st vertebra, is brought about by means of a ligament. For it is but rarely the case that the latter is ossified: in the Cyprinoidei a shorter or longer part of it is ossified; and as the ossification takes its beginning from the proximal end, it has the appearance of being a "transverse process" of the 1st vertebra; but in nearly all the Siluroidæ (viz., with the exception of Clarias) this ligament is a more or less considerable bone, the strength of which, as well as the manner in which it is connected with the occipitale, is in relation to the size of the first ray of the pectoral fin, and whether the "suprascapula" is connected with the transverse process of the (real) 4th vertebra or no. Ten years ago I had already pointed out this fact in my first paper (II*b*, pp. 3 and 21). And in both my papers I have proved that in Clarias there exists no connection whatever between the "suprascapula" and the occipitale basilare, because the said ligament has not been able to form itself, the accessory gill-cavity, in which the air-breathing dendritic organs are inclosed, being placed where the ligament should be, and has therefore, if I may say so, supplanted it. In return, the pectoral girdle has in this genus been strengthened by the helmet (the dermoidal bones) having attained to a size unparalleled in all other Siluroidæ except when the large (2nd) ray of the dorsal fin is a very effective weapon—in Clarias it is no weapon at all, but a mere weak ray, and the preceding "rudimentary" ray is here wanting.

If the authors had known the true nature of this "inferior limb" of the post-temporal, and the importance of the degree of the development of this bone in these animals, they would never have been "tempted to think that the post-temporal plates of Macrones and the allied genera might represent a form of 'elastic spring' mechanism" (p. 245). For, neither from a morphological nor from a physiological point of view, have these two things anything to do with each other. But, as I shall

prove in the following pages, the authors had, in their Memoir in the *Transactions* of the Royal Society, completely overlooked my first paper.

I.

Are the extrinsic muscles of the air-bladder in some Siluroidæ and the "elastic spring" apparatus of others, subordinate to the voluntary production of sounds?

> *Πάντα δὲ ταῦτα τὴν δοκοῦσαν φωνὴν ἀφιᾶσι . . . τὰ δὲ τοῖς ἐντὸς τοῖς περὶ τὴν κοιλίαν. Πνεῦμα γὰρ ἔχει τούτων ἕκαστον, ὃ προστρίβοντα καὶ κινοῦντα ποιεῖ τοὺς ψόφους.*
>
> —*Aristotle.*

While Professors Bridge and Haddon agree with me in the opinions I have propounded as to the morphology of the skeletal elements treated in my second paper (III.), I cannot, I am sorry to say, pride myself on this concurrence as to the physiology of the air-bladder in the Siluroidæ treated in my first paper (II*b*). In order to show this, I shall take the liberty to quote some remarks by the said authors in their detailed account of the "Physiology of the Air-bladder and Weberian Ossicles in the Siluridæ" (I*b*, pp. 261–303). Page 269:—

"In addition to the various other methods by which voluntary sounds are produced in different fishes, the air-bladder not unfrequently shares in the function of phonation. Such sounds are either produced by the vibration of the internal annular diaphragm (Moreau), or by the vibration of certain extrinsic muscles (Dufossé [1]), the air-bladder in the latter case intensifying the sound produced by acting as a resonator. Dufossé (*loc. cit.*) is also of opinion that some Ostariophyseæ (*e.g.*, some Cyprinidæ and one or two Siluridæ) produce breathing noises ('les bruits de souffle') by the expulsion of gas from the air-bladder through the ductus pneumaticus, and it has been suggested [2] that the grunting sounds emitted by Clarias have

[1] The first paper of this author here referred to. (Va: Dufossé, *Recherches sur les bruits et les sons expressifs que font entendre les Poissons d'Europe . . . Annales d. Sci. Nat. 5 Sér.*, T. xix. Paris, 1874. Art. No. 5.)

[2] By whom?—Day, to whom Bridge and Haddon refer in a paper entitled "Instincts and Emotions in Fishes" (*Jour. Linn. Soc.*, xv., 1881, pp. 31-58) only says as follows:—"Sir Emerson Tennent observed that a Siluroid fish (Clarias) found in the lake at Colombo is said by the fishermen to make a grunt

a similar origin. *The possibility that the Weberian ossicles have any thing whatever to do with phonation, either in the Siluridæ or in other Ostariophyseæ, is very remote,*[1] and need be but briefly considered."

Page 270: "We are strongly inclined to the opinion that although sounds may indirectly have their origin in the air-bladder, *they have no relation to it other than as accidental accompaniments in the exercise of its normal hydrostatic function,*"—with the following footnote: "For these reasons, and *in the absence of definite experimental evidence*, we cannot at present accept Sörensen's *ingenious theory* that the extrinsic muscles of the air-bladder in the Pimelodinæ, and the 'elastic-spring' apparatus of other Siluridæ, are solely subordinate to the voluntary production of sounds." "In one example cited above (Clarias) it is almost certain that the grunting sound which the fish is said to make could not be caused *by the voluntary expulsion of gas from the air-bladder*, inasmuch as this organ is not only rudimentary, but almost completely encapsuled by bone. Eliminating such doubtful examples of the association of the air-bladder with phonation in a few Siluridæ and Cyprinidæ, it may be urged with regard to the rest that the comparative[2] rarity of *well authenticated instances of the production of voluntary sounds*, the absence of extrinsic muscles in all but a few genera (Pimelodinæ), and *the want of internal vibratory diaphragms, or other obviously vocal structures, are quite sufficient to prove that the air-bladder takes little or no part in this function, at all events, by any of the ordinary methods known in other Fishes.*"

P. 296: "In the great majority of the Ostariophyseæ the escape of air from the air-bladder through the ductus pneumaticus apparently takes place only as the result of the expansion of the contained gases under the influence of diminished hydrostatic pressure, although it is possible that the rate of overflow may in some way be regulated. In some few Siluridæ, however, there does seem to exist a special

under water when disturbed." And in saying so he is almost literally quoting Sir Emerson Tennent, whose words run as follows (*Ceylon.* Fifth edition, vol. ii., Lond. 1860, p. 470):—"The fishermen assert that a fish, about five inches in length, found in the lake at Colombo, and called by them 'Magoora,' makes a grunt when disturbed under water." Bridge and Haddon, indeed, quote a paper by Day bearing the very same title, and to be found in the *Transactions of the Zool. Soc.*, vol. xv., 1880; but nowhere in the *Transactions* of this Society, neither in vol. xv. nor in the volume published in 1880, there exists such a paper. I therefore presume that they refer to the paper which I have mentioned, the more so as *the references in the physiological division of their work*, with the exception of the references to their own papers, to those of Ramsay Wright, and to Günther's "Introduction," are wanting in precision.

[1] The italics in this and the following quotations are mine.

[2] The Siluroidæ are, among all families of Fishes, the one which, before the time of Dufossé, counted the greatest number of species known as sound-producing—both Platystoma Orbignyanum, Pseudaroides clarias, and 2–3 species of the genus Doras, for instance, were known as such by Cuvier and Valenciennes. The statements of naturalists as d'Orbigny and Charles Darwin, Professors Bridge and Haddon, will not, I suppose, design as being not "well authenticated."

mechanism *by which, under certain conditions, the air-bladder may be subjected to considerable compression, and the air which it contains either forcibly expelled, or greatly reduced in volume by condensation* [Moreau!].[1] This mechanism presents two important modifications, viz., the "elastic spring apparatus" and the powerful extrinsic muscles of the Pimelodinæ."

Pp. 297–298:—"The mobility and elasticity of the transverse process which forms each spring will certainly give to the lateral portions of the anterior wall that capacity for sharing in the distension of the anterior chamber which is prevented in all other Siluridæ by the absolute rigidity of the processes in question, but it is at the same time, equally clear that the 'elastic spring' apparatus cannot possibly give the fish any power of directly compressing the air-bladder, except under certain conditions, viz., when the anterior chamber becomes distended through the diminution of pressure which occurs in movements of ascent, coincidently with the forward movement of the two springs as the result of the voluntary or reflex contraction of their protractor muscles. Under such circumstances the [elastic spring,] mechanism potentially acquires the power to modify the capacity of the air-bladder, for the subsequent relaxation of the muscles will at once enable the springs, through the force of their own recoil, to exert their full strength in compressing both the air-bladder and its gaseous contents." And to the words "gaseous contents" is added in the form of a footnote:—"Should this view of the mode of action of the 'elastic spring' apparatus prove correct, *it will be difficult to see how the mechanism can have anything to do with the production of voluntary sounds*, as suggested by Sörensen, *inasmuch as the Fish would only be able to exercise its vocal powers under conditions involving pressure reduction during ascent from a deeper to a more superficial level. Under such conditions only does it seem likely that the contained gases would be expelled with sufficient force to produce any definite or characteristic sounds.*"

P. 300:—"The Extrinsic Muscles of the Air-bladder in the Pimelodinæ.—A function substantially similar to that of the 'elastic spring' apparatus may, in all probability, be assigned to the powerful

[1] The authors have perused Moreau's paper (VI. Moreau, A.: "Recherches expérimentales sur les fonctions de la vessie natatoire": *Annales d. Sci. Nat.*, 6 *Sér.*, T. iv. Paris, 1876. Art. No. 8), but they have not *studied* this most excellent memoir. Otherwise, they would have noticed his remarks (p. 52) which may regard also the theory of Joh. Müller about the function of the "elastic spring" apparatus in some Siluroidæ: "L'attention des savants n'avait pas été encore fortement appelée sur les phénomènes de la contraction musculaire sur la fatigue que le travail musculaire engendre et par conséquent sur l'invraisemblance d'efforts aussi prolongés et aussi énergiques que ceux que suppose la théorie traditionelle." For the very same objection may be urged against the above-cited opinion, nay, against all suggested by Bridge and Haddon on the function of the "compressor" muscles and the "elastic spring" mechanism. In the passages of these authors which I am going to quote on the following pages, I take the liberty to add the word ["Moreau!"] to similar remarks.

compressor muscles of the Pimelodinæ.[1] *These muscles cannot possibly have any share in dilating the air-bladder* and rarefying the contained gases in order to facilitate ascent, but it would certainly seem that they enable these particular Siluridæ to exercise a still more effective control over its distension, *inasmuch as the muscles are apparently able to compress the air-bladder at all times*, although more effectively, no doubt, when the latter is more or less distended [Moreau !]. By the contraction of these muscles during rapid movements of ascent the tendency to over-distension on the part of the air-bladder will be promptly counteracted, while a forcible expulsion of gas through the pneumatic duct would enable the Fish to speedily adjust its volume and specific gravity to a new plane of least effort at the more superficial level. . . . . In both series of Fishes it is extremely interesting to recall the existence of a special arrangement by means of which the compression of the air-bladder, either by the action of the 'elastic springs' or by the contraction of special *compressor* muscles, is prevented from imparting a too violent shock to the Weberian mechanism, and more especially to the fluids and sensory epithelia of the internal ear. . . . . . *The extreme difficulty of attempting to arrive at a satisfactory solution of* the various problems arising out of the physiology of the air-bladder, *through anatomical data alone*, is again forcibly illustrated, for *it is impossible entirely to exclude the possible relation of the extrinsic muscles of the Pimelodinæ to the function of sound production, and it may also be the case, although perhaps less likely, that the same reservation will also apply to the 'elastic spring' mechanism. That a violent expulsion of air from the air-bladder should produce definite sounds is extremely probable*, but how far such sounds can be considered as related to the primary function of these muscles, or as merely accidental concomitants to it, must for the present remain an open question. Sörensen has adopted the former suggestion, and regards both the *compressor* muscles and the 'elastic spring' mechanism as being subordinate to sound production. Nevertheless, *in the absence of confirmatory experimental evidence*, we still think it worth while to direct attention to an alternative interpretation of the function of these structures, which is at least as consistent with their morphology as any other view at present suggested. We have elsewhere (p. 270 and p. 298) suggested certain difficulties, which, in our opinion, are *serious* objections to Sörensen's views on this point."

To everybody who has perused these quotations from the work of Professors Bridge and Haddon, it will now be evident that these authors have set forth the following suggestions:—

1. *That the function of the "protractor" muscles of the "elastic spring" mechanism in some Siluroidæ consists in pulling forward*

[1] I beg to direct the attention of the reader to the fact, that, as will appear from the above quotation, the authors are of opinion that the effect produced by the protractor muscles of the "elastic spring" apparatus is nearly quite the reverse of the effect produced by the extrinsic muscles of the Pimelodina.

the springs, in order to enable the air-bladder to distend itself in front, and that the effect which they produce is therefore nearly quite the reverse of the effect produced by the extrinsic muscles, the so-called "compressor" muscles, of some other Siluroidæ.

2. *That all "internal vibratory diaphragms or other obviously vocal structures" are completely wanting* in the air-bladder of these fishes.

3. *That without confirmatory experimental evidence I have propounded a "theory," nay, an "ingenious" one, of the "elastic spring" mechanism and the extrinsic muscles being subordinate to the production of sounds.*

4. *That these sounds are produced by "a violent expulsion of air from the air-bladder."*

5. *That the authors have entirely crushed this theory.*

I am quite willing to acknowledge that they have completely succeeded in doing so. This victory has but one deficiency: that what they have succeeded in conquering, are—the windmills of Montiel! For the opinion which they impute to me, I never had nor suggested.

But why, then, do they impute this theory to me? Firstly, because they had entirely overlooked my book, *Om Lydorganer hos Fiske*, and had not formed an idea as to the contents of this work by perusing its "explicatio figurarum"[1]; and secondly, because, even if they themselves had not been fully aware of the fact, they were under the influence of the first paper, written in modern times, "On the Origin of Sounds produced by Fishes"[2]—a paper by no means worthy of the eminent genius of its author.

In this paper Joh. Müller says:—

> "Im Munde jedes Fisches können, wenn er sich in der Luft befindet, Lufttöne entstehen, gleichviel ob er eine Schwimmblase besitzt oder nicht, ob die Schwimmblase geschlossen ist oder einen Luftgang in den Mund besitzt. Dagegen kann bei einem Fische, der unter Wasser tönt, an Lufttöne nur dann gedacht werden, wenn er einen Luftgang der Schwimmblase besitzt und wenn dieser hinreichend weit ist, *um Luft plötzlich auszutreiben.*"

[1] The names of the Siluroidæ, the air-bladders of which are represented among the figures, are, however, recited in their memoir.

[2] VII. Müller, Joh.: Ueber die Fische, welche Töne von sich geben, und die Entstehung dieser Töne (*Archiv f. Anat. u. Physiol.* Berlin, 1857, pp. 249–279).

For as Horace says :—

Quo semel est imbuta recens, servabit odorem
Testa diu.

If the authors had perused the Latin "explicatio figurarum" in my paper, they would have observed that wherever I have represented muscles, which make the air-bladder act as a sound-producing organ (if only one pair of such muscles do exist), I have designated each of these muscles as "musculus, cujus contractione *sonat* vesica natatoria," whether the fishes mentioned be furnished [1] with a ductus pneumaticus or no.[2] But how could it have been possible to suggest it as my opinion that (extrinsic or intrinsic) muscles of an air-bladder, *without* a pneumatic duct, might ever be able to produce sounds by "a violent expulsion of the air from the air-bladder"? Or, how could I ever—if I had but the slightest notion of the meaning of the Latin words—say, "*sonat* vesica natatoria," if the contraction of the muscles were to effectuate the expulsion of air from the air-bladder?

But if the authors had only read a short remark of mine in "les Comptes rendus,"[3] or in the "Annals,"[4] where it had been translated from "les Comptes rendus," they would have seen that what I have suggested on the production of sounds by means of the air-bladder in the Siluroidæ [5] in question, is quite different from what they impute to me; for in the passage quoted from the "Annals," my words have been thus translated :[6]—"In the Siluroidæ [5] the anterior portion of the swimming-bladder is drawn alternatively forward and backward by the contraction and relaxation [7] of the muscles. During these movements the air, in passing across the incomplete transverse septa, sets the

[1] Pseudaroides clarias (fig. 45); Synodontis schal (fig. 48).

[2] Diodon hystrix (fig. 49); Batrachus tau (fig. 60); Micropogon undulatus (fig. 61).

[3] II*a*: Sörensen, William, "Sur l'appareil du son chez divers Poissons de l'Amérique du Sud" (*Compt. rend. de l'Acad. d. Sci.*, T. lxxxviii. Paris, 1879, pp. 1042–43).

[4] *Annals a. Mag. of nat. hist.* 5 Ser., vol. iv. London, 1879, pp. 99–100.

[5] Doras maculatus, Platystoma Orbignyanum ?, Pseudaroides clarias.—The remark also refers to some genera of the Characini.

[6] I readily agree that, on account of its brevity, this summary is not quite clear. As to the manner in which the production of sounds itself is operated, I do not think, however, that it can easily be misunderstood.

[7] I have not succeeded in finding the correct words to express my idea, as may be seen later on from the quotation of my book.

latter in vibration, and the sound is produced. The height, or rather the depth, is in direct proportion to the rapidity of the vibration of the springs."

And if the authors had known a most valuable paper by the late M. Dufossé[1] on the air-bladder as a sound-producing organ, in a fairly considerable number of Fishes (16 species, 7 genera), all without a pneumatic duct, they would have seen that my "theory" was quite in accordance with the result at which this skilful French author had arrived through his examinations—not in his study, but—of living animals. Then, certainly, the authors would not have said that the production of sound, according to my "theory," was not effectuated "at all events by any of the ordinary methods known in other Fishes." And then they would not have spoken about "the want of internal vibratory diaphragms . . . . ." *inasmuch as they themselves have described and represented such diaphragms (the "transverse septa") in a considerable number of Siluroidæ—even to the number of six pairs!*

However, even if the opinion which I had suggested was in accordance with the result obtained by Dufossé in his examinations of living fishes, Professors Bridge and Haddon might be entitled to call my opinion a "theory" if, what they evidently supposed me to have done, I had stayed in Copenhagen and "construirt" my "theory" "aus dem Inneren meines Bewusstseins." For that is exactly the way by which they have arrived at the opinions which they have suggested on the function of the air-bladder and the Weberian ossicles in the Siluroidæ.

So I must ask the reader to observe the full title of my book, *On Sound-Producing Organs in Fishes, a Physiological and Comparative Anatomical Research*, my intention being to intimate, in as few words as possible, that my results had been obtained in both ways—vivisection with regard to some forms, and examination of dead animals with regard to others.

Now, my examinations of Siluroidæ and Characini happen to be the basis of my paper, as I *commenced* these studies at the confluence of the Riacho del Oro with the Rio Paraguay.

[1] *Vb*: Dufossé, "Recherches sur les bruits et les sons expressifs que font entendre les Poissons d'Europe . . ." (*Annales d. Sci. Nat.* 5 Sér., T. xx. Paris, 1874. Art. No. 3).

It must now be investigated whether my opinion about the function of the air-bladder and the extrinsic muscles or the "elastic spring" mechanism be a "theory" or no.

About *Doras maculatus* (Cuv. et Val.), I say in my paper, after having described (pp. 85–87) the structure of the air-bladder (*vide* figs. 1 and 2), as well as the "elastic spring" mechanism and its muscles, and after having pointed out the fact that the "malleus" (in this genus) is also a spring, p. 88, as follows:—

"*Observations on the Production of Sounds.*—When the belly of the recently caught fish is opened, and the intestines with their append-

FIG. 1.—*Doras maculatus*, Cuv. et Val. The air-bladder of a specimen, measuring 50 cm. of length, seen from below. Diminished thrice. To the right the ventral wall of the air-bladder has been removed. The cæcal diverticula are not represented on this side. *dv*, one of the circular bony plates (fused with the hinder part of the muscular spring, the transverse process of the (real) 4th vertebra) in the fore end of the wall of the air-bladder. In a living specimen it is not so prominent in proportion to the remaining part of the air-bladder.

ages are taken out quickly, so that the air-bladder is laid open, it may be very easily observed that the air-bladder is in a state of convulsive vibration, at the same time as sounds are produced.[1] This sound

[1] A part from the sounds produced by the movements of the fins.

is a very deep, growling tone, which is so intense that *it is still to be heard very distinctly at a distance of* 100 *feet*[1] when the fish is *out of the water*. In contradistinction from the sound produced by the movements of the pectoral fins, the sound produced by the air-bladder is not discordant, and therefore it is not disagreeable to the ear. As far as I have been able to catch—I am sharp of hearing, but I have some difficulty in distinguishing notes—the air-bladder only commands one tone, but this tone may be more or less strong as it pleases the fish. If you move your fingers backwards and forwards on the air-bladder, you will soon perceive that the vibrating movement, arising at the same time as the sound, is strongest in front, especially near the muscular springs, and likewise that the muscles inserted upon the similar plates of these springs are contracted at the same time as the sound arises. If the muscles are cut asunder, the sound[2] is no more produced. If a small hole is made in the air-bladder (when the muscles are uninjured) the sound does not grow much fainter, but if the hole is enlarged the sound loses considerably in strength. If the

FIG. 2.—*Doras maculatus*, Cuv. et Val. The same specimen. The end of one of the large (posterior) cæcal diverticula of the air-bladder. It is opened, so as to permit a survey of its cellular structure. Natural size.

air-bladder is removed, the sound grows much fainter, but is still audible; then it is exclusively produced by the vibration of the springs. By direct observation I have not been able to prove that the beams of the principal chamber of the air-bladder, or the incomplete transverse septa of its cæcal diverticula, contribute to the production of the sound; but if the reader will compare this with what I am going to communicate in the following pages by *Pseudaroides*, I am of opinion that it will prove *without doubt* that the cæcal diverticula of the air-bladder, on account of the incomplete internal transverse septa (fig. 2), are most intimately concerned in the function of intensifying the sound by means of the air passing forwards and backwards above the septa. By a minute examination it may be observed that the foremost of the bony scutes on the side of the body shares in the vibration when the sound is produced. I presume that the

[1] A Danish foot is a little longer than an English.

[2] Apart from the sounds produced by the movements of the fins.

function of the ligament [1] serving to connect this plate with the circular plate of the muscular spring, does not only consist in transmitting the sounding vibrations of the air-bladder to the water, but also in preventing a too violent reaction of the spring when the muscle is relaxed."

After having described the air-bladder and its extrinsic muscles (p. 92) in *Platystoma Orbignyanum?* Val.[2] and *Pseudaroides clarias*, Bl., and having proved the "malleus" (the "tripus," Br. and Hadd.) to be a spring, I continue (p. 93) as follows:—

"*Observations on the Production of Sounds.*—When the air-bladder of the living animal is laid open, it is very easy to perceive that the muscles in question are contracted at the same time as a strong, deep, growling sound is produced, while the wall of the air-bladder is set into a strong, vibrating motion. The majority of the specimens I have examined of Pseudaroides were not above a total length of 25 to 35 cm. Hence the walls of the air-bladder were not so thick as to prevent me from distinguishing, without opening the air-bladder, the internal transverse septa in the shape of darker transverse stripes; therefore, I was able to observe very distinctly that, during the emission of the sound, they were swinging (or being moved) very quickly to and fro (fig. 3).

This fact is sufficient to prove that they play a very important part in serving to intensify the sound, by means of the air vibrating above their edges from one chamber to another. If a small hole is made in the air-bladder of a Platystoma, the intensity of the sound is not diminished in any remarkable degree. But if a fissure, however small, is made in the air-bladder, the sound grows distinctly fainter, and at last quite ceases, even if the muscles are still in action.

As far as I have been able to observe, as is the case in Doras, only one contraction of the muscles takes place every time a sound is produced. This sound always lasts for a certain time, grows fainter toward the end, but suddenly ceases. On the nature of the sound the same may be said as I have stated about Doras. The sound produced by a Platystoma [3] is audible at a distance of more than 20 feet if the animal is on shore."

[1] This ligament connects the distal circular plate of the "elastic spring" with the foremost, hardly visible, of the thorny dermoidal plates, which in this genus are placed on the side of the body. A corresponding ligament I have not found in any other genus of the Siluroidæ furnished with the "elastic spring" mechanism.

[2] Professor Lütken, who was then so kind as to determine the Siluroidæ which had been the object of my examinations, was not able to determine with exactitude this species, as I had not brought home any uninjured specimens. But at any rate it is *not* Pl. fasciatum, as related by Bridge and Haddon (*Ib*, p. 118). For, according to Joh. Müller, it is easy to distinguish the air-bladder in this species from that which I have examined.

[3] The specimens examined generally had a length of 1 metre, or somewhat less.

I ought to have added that the sound is no more produced when the muscles are cut. Whether, by this operation, I have cut the pair of small muscles (M. "tensores tripodium," Br. and Hadd.) which Bridge and Haddon have always found along with the large extrinsic muscles I do not know, as I have not seen these muscles; I suppose it to be so.

As it was of some importance in connection with the subsequent comparative-anatomical part of my book, I added:— "From the description of the air-bladder of these three genera it is evident that, particularly in Platystoma and Doras, it is so 'cellular' as is but rarely found in fishes; nay, *Doras maculatus*

FIG. 3.—*Pseudaroides clarias*, Bl. The air-bladder of a specimen measuring 39 cm. of length, seen from below. To the right the ventral wall of the air-bladder has been removed, so as to permit the survey of the internal transverse septa, which divide its lateral halves into compartments. (By this operation a small part of the septa has been removed.) Diminished twice. *msv*, one of the muscles, which make the air-bladder act as a sound-producing organ; *r*, the kidneys behind the air-bladder, cut off from behind; *r'*, the pronephros.

seems to be of all fishes (perhaps with the exception of Gymnarchus) the one whose air-bladder contains the greatest number of 'cells.'"

As may be observed, this is in perfect accordance with the words of Bridge and Haddon (I*b*, p. 236):—

"It may be remarked that cæcal appendages are very characteristic of those Siluroids in which an elastic spring 'apparatus' is present."[1] And in this connection it is well worth noticing what the authors add:—"A branching condition of the air-bladder, with the branches

[1] Not, however, in Synodontis, Malapterurus, and Euanemus.

ending in cæcal extremities, is very common in certain Physoclist genera. . . ."—See Günther,[1] p. 144–145.

For the genera mentioned in this place by Dr. Günther belong, with the exception of Polynemus, to the Sciænoidei, which are known to produce sounds by means of the air-bladder.

I myself was also struck with a similar very obvious idea, as may be seen from the following lines, a repetition in nearly the same words of what I wrote ten years ago (II*b*, pp. 107–109):—"Being engaged in the above-mentioned investigations at the mouth of the Riacho del Oro, where it enters Rio Paraguay, I was quite unacquainted with what had been published on this subject. I only knew that *Cottus scorpius*,[2] *Trigla* (*gurnardus*), and *Dactylopterus volitans* are sound-producing. But having arrived at the result that the muscles of the air-bladders, which I had examined, serve to throw the air-bladder into sound-producing vibrations, and that a divided[3] air-bladder offered an improved organ for the production of sounds, I consulted V. Carus (and Gerstaecker's) *Handbuch der Zoologie*, which book was my only literary resource in South America, to see if any sound-producing fishes were mentioned there. This, it is true, was not the case; but as to Dactylopterus, the author

[1] XIII. Günther, A. C. L. G., "Introduction to the Study of Fishes," Edinburgh, 1880. The authors here also refer to Günther's *Catalogue of Fishes in the British Museum*, vol. v. But as this volume only contains Physostome fishes, I do not understand this reference.

[2] I have shown (II*b*, p. 78) that this fish produces sounds by stridulating between the præoperculare and the hyomandibulare. Dufossé (V*b*, pp. 91–103) and Professor L. Landois (in a book, *Thierstimmen*, Freiburg in Breisgau, 1874, published by his brother, Dr. H. Landois) judge the sound emitted by this fish to be due to the vibration of certain muscles. But while Dufossé designs these muscles as ". . . des muscles qui . . . font partie des régions inférieures des appareibs : hyoïdien, branchial et pharyngidien," Landois is of opinion that these muscles are the muscles of the shoulder-girdle. I have had no opportunity to resume this investigation after the perusal of the book of Landois.

[3] In the air-bladder of the Characini, examined by me, there is no further division but the well known one into an anterior and a posterior chamber; in *Platystoma orbignyanum* (?) and *Pseudaroides clarias* (see fig. 3 above) the air-bladder is divided into one large anterior chamber and five to six pair of chambers, growing gradually smaller behind and communicating with each other and with the first chamber by means of, comparatively speaking, large apertures along the lateral wall of the air-bladder; in *Doras maculatus* (see figs. 1 and 2 above) it is but partially divided by a longitudinal incomplete septum, and provided with numerous finger-like cæcal diverticula, among which the largest are incompletely divided in cells.

says (p. 539), "Schwimmblase getheilt, mit Muskeln;" and about Trigla (p. 538), "Schwimmblase wie bei Prionotus:" "Schwimmblase meist mit seitlichen Muskeln und in zwei Theile gespalten." Without knowing that this fact had already been stated by Dufossé,[1] I drew the obvious conclusion that Trigla and Dactylopterus also produce their sounds by means of the air-bladder, and that Prionotus was a sound-producing fish. In no other genera except these three muscles (extrinsic or intrinsic) were mentioned. But from what was stated about the form of the organ in the different genera, I arrived, by means of a vague conclusion, it is true, at the mere preliminary supposition with regard to twenty-six other genera or families, that the air-bladder might act as a sound-producing organ.

I am not going to fatigue the reader with a detailed account, but I shall confine myself to remarking that this idea proved correct,[2] so that, by means of my own investigations as well as by those of my predecessors, and more especially those of Dufossé, I was able to establish the following general thesis (II*b*, p. 182):—"*Where the air-bladder is a sound-producing organ, this organ is rendered the more effective, the thicker its walls are; the stronger or more elastic they are; the more it is divided into chambers* (and it is without any importance whether this division is brought about by external diverticula or by internal septa); *the more vigorous the musculature is*, and, in consequence, *the more closely it is connected with the skeleton*, provided the musculature be not intrinsic muscles. When these conditions are found together, we may determine an air-bladder as an organ producing sounds. As yet, however, with the restriction, *that the air-bladder must be either closed or furnished with a long, narrow, thin-walled pneumatic duct.*

For when the pneumatic duct is short and wide, and opens into the œsophagus with a fissure-like aperture, the *possibility* is

[1] The paper of Dufossé, dealing with this matter, was published in 1874, when I was a soldier, and I left Denmark in 1876, having never before been engaged in independent anatomical examinations of fishes.

[2] Among the twenty-six genera (or families) species producing sounds were known, or are now known: the Sciænoidei, Batrachus, Polypterus, Ceratodus, Lepidosiren, and Protopterus; muscles (extrinsic or intrinsic) were known in Therapon, Holacanthus, the Sciænoidei, Batrachus, Amblyopsis, Heterotis, Gymnarchus, Amia, Polypterus, and Lepidosiren.

not excluded, that this pneumatic duct may be capable of admitting the passage of the atmospheric air to and from the air-bladder, and in this case, therefore, it is possible that the latter may operate as an organ of respiration.

Besides the fishes, of which the anatomy is known to me through autopsy (Polypterus and Acipenser), information may be found in literature that the pneumatic duct is short and wide in Protopterus, Ceratodus, Spatularia, Arapaima (Sudis); Gymnarchus, Heterotis, Lepidosteus, Lepidosiren (in which four genera, according to the examinations of Hyrtl, the air-bladder is provided with muscles), as well as in Amia (in which, according to Franque, the air-bladder is provided with muscles). Now, it is true that several authors, on account of the anatomical data, have declared the air-bladder to be a lung in the following genera:—Arapaima (Sudis), Polypterus, Lepidosteus, Amia, Ceratodus, Protopterus, and Lepidosiren. But though it has, indeed, been observed that these fishes—with the exception of Polypterus[1]—are inhaling atmospheric air, still it is worth remarking that there exists no proof whatever[2] of the atmospheric air, respired by these fishes, being carried down into the air-bladder, as is absolutely necessary if the air-bladder is to be considered an organ of respiration.

In my book (II*b*, pp. 183–204) I have proved, as far as I can judge, that the reasons for attributing to the air-bladder the function of a lung, are anything but satisfactory. As I am here addressing myself to English-speaking naturalists, I shall confine myself to mention the Ceratodus and Protopterus, as these fishes have been repeatedly treated in English literature. The idea of attributing to the air-bladder the function of a lung arises from the *Lepidosiren paradoxa*, whose gills are so few and so small that most probably they cannot be sufficient to provide for the respiration of the animal. When this remarkable fish

[1] A sister of mine, Mrs Ida Leschly, who spent some years in Egypt, obtained information about the biology of this fish from the Egyptian fishermen. They unanimously stated this fish to live at the bottom of the river, and none of them ever saw an "Bichir" rising to the surface of the water to respire (whereas they were fully aware of the fact that such was the habit of the genus Clarias). One fisherman declared that he had heard it producing sounds in the water, but never out of it. Out of the water it is said to live only a few hours, though it is very tenacious of life.

[2] I must here remark that I have not followed these questions since 1884.

was treated in literature, no air-breathing fishes were known except the Cobitis; hence it was quite natural that, in the discussion on the Lepidosiren, no attention was paid to this isolated fact, the more so as this discussion turned chiefly upon its systematic position,—for, as is well known, it was considered by many naturalists as belonging to the Batrachia. No wonder, therefore, that the authors immediately agreed on the suggestion, that on the "lung," as it was called, was ingrafted the function of a respiratory organ. However, the probability that the air-bladder is really acting as a lung in this animal is somewhat confirmed by Dr Bohls[1]—

"Die Bedeutung der Lunge als Respirationsorgan kennzeichnet sich bei den lebendfrisch geöffneten Tieren durch die hellrote Farbe, die sie dem arteriell gewordenen Blut verdankt." When the author adds: "Die von mir gehaltenen *knurrten* beim Anfassen, ein Laut, der erzeugt wurde durch Auspressen der Luft aus den engen Kiemenöffnungen."

This explanation of the manner in which the sounds are produced appears to me rather doubtful.

The question was then proposed if the air-bladder was not to be considered a respiratory organ in other fishes, where it is cellular. Joh. Müller, meeting with an air-bladder of this kind in some Siluroidæ and in Erythrinus, thought fit[2] to reduce the question to a more definite form, and he answered it to the effect that the air-bladder in the Lepidosiren was to be considered a respiratory organ because of its receiving ("dark") blood from and returning ("light") blood to the heart, but that this was not the case either in the Polypterus, the organ in this fish receiving blood from the fourth gill-vein, and returning blood to the liver-veins, or in the Erythrinus, where it received blood from the arteries of the body, and returned blood to the veins of the body. This distinction, which is obviously founded on relations in the superior Vertebrata, was generally adopted, and is still considered decisive—thus Moreau calls it "les justes remarques." And yet it is incorrect, nevertheless. For the

[1] Bohls, "Mittheilungen über Fang und Lebensweise von Lepidosiren aus Paraguay," *Aus. d. Nachricht d. k. Ges. d. Wiss.*, Göttingen, 1894, No. 2.

[2] VIIIc: Müller, Joh., "Untersuchungen über die Eingeweide der Fische: Schluss der vergleichenden Anatomie der Myxinoiden" (*Abh. d. k. Akad. d. Wiss. zur Berlin*, A. d. J. 1843, Berlin, 1845, pp. 109–170).

physical principle of respiration is, that the blood enters into so close a relation with the air (atmospheric air, or air absorbed in water) that by a diosmosis a change of matter may be effected between the air in the blood and that without. And it is of no consequence whether the respiring capillaries are ramifications of an artery or of a vein. Consequently, an animal is able to respire with any part of its body provided that this part can enter into contact with the air: the outer skin, the cavity of the mouth, the gill-cavity, the intestines, the gills, or the lung. That the skin in Fishes shares in the respiration has already been shown by Spallanzani,[1] Provençal and Humboldt.[2] To what degree it shares in this function has not yet been proved, as far as I know; probably it does so in a rather great measure. But, on the other hand, respiration cannot take place when the air which, having been in contact with the respiring part of the body, has been rendered incapable of continuing the respiration, is not replaced by fresh air—that is, provided the respiring superficies is placed inside the body (gills, lung, intestines), by mechanical respiration. Whether an internal organ is an organ of respiration may therefore be decided by examining if it is the seat of mechanical respiration, which is, to a certain extent, constant, and whose continuation is necessary for the animal's existence, at least under certain circumstances. If we confine ourselves to the air-bladder, it has already been proved by Delaroche at the beginning of this century, and still more conclusively by Moreau, that there exists a constant exchange between the air in the air-bladder and the air in the blood,[3]

[1] Spallanzani, L., *Mémoires sur la respiration*, traduits par J. Senabier, Genève, 1803, pp. 113–114.

[2] IX. Provençal et Humboldt, "Recherches sur la réspiration des poissons," p. 392 (*Mémoires de physique et de chimie, de la société d'Arcueil*, T. II., Paris, 1809, pp. 359–404).

[3] The quantity of carbonic acid is variable. According to Moreau, in Perca, when normal, scarcely 1 per cent. is found, and in Barbus ½ per cent.; but the author, who unfortunately gives no details of his examinations, says in general: "Les proportions d'acide carbonique sont généralement au-dessous de 10 per cent. et même au-dessous de 5 pour 100." Schultze, Fr. ("Ueber den Gasgehalt der Schwimmblase einiger Süsswasserfische Deutschlands." *Pflüger's Archiv. f. d. gesammte Physiologie*, V. Bonn, 1872, p. 48–52), found in Barbus 1·4–4 per cent., and in Tinca 3·9–5·4 per cent. Schultze pretends to be, in 1872, the first author who has found the carbonic acid in the air-bladder. Without being thoroughly versed in this question, I know several authors previous to Schult

and yet it is no organ of respiration. It cannot be called so unless its air is renewed by mechanical respiration. If that be the case, it is an organ of respiration, no matter whence its blood comes and where it goes. Not to mention that (according to Hyrtl) the accessory gill-cavity in Saccobranchus receives some vessels from (and returns to) the adjoining parts of the body, and that (according to Jobert) the intestinal tube in Callichthys receives blood from the aorta, the venæ cavæ, and the vena porta renalis, there is another fact, pretty well known, which has no reference to the Fishes, which proves the untenability of the distinction set up by Joh. Müller. It is a well-known fact that the inwardly smooth hinder part of the lung in Snakes and in certain Sauria receives blood from the aorta. In accordance with the distinction of Joh. Müller, this fact is constantly interpreted to the effect that the hind part of the

who have made this observation. Moreau found carbonic acid in several Fishes ("Sur l'air de la vessie natatoire des poissons." In *Compt. rend. d. l'Acad. d. Sci.*, T. LVII., Paris, 1863, pp. 816–20). Humboldt found 2 per cent. in Exocœtus (*Reise in die Aequinoctial-Gegenden des neuen Continents*, I. Stuttgart, 1859, p. 179) and 4 per cent. in Poecilia Bogotensis (Humboldt et Aimé Bonpland: *Recueil d'observations de zoologie et d'anatomie comparée* . . ." T. II., Paris, 1833, p. 155). Provençal et Humboldt, in 1809, found 5·2 per cent. in Cyprinus carpio (IX., p. 401), and in 1789 Fourcroy found carbonic acid in Cyprinus carpio ("Observations sur le gaz azote contenu dans la vessie natatoire de la carpe" . . . in *Annales de Chimie*, I., Paris, 1789, pp. 47–51). If the author had consulted Cuvier, *Leçons d'anat. comp.*, he would have found (Edit. 2, T. VIII., p. 724) two of the authors mentioned, to whom I have referred here. When he says with regard to the two authors Biot and Erman, with whose papers he has made himself acquainted: "Dass die älteren Beobachter fälschlich einen vollständigen Mangel von CO_2 behauptete, eine Thatsache, die ihnen allerdings unerklärlich schien, die sie aber als solche hinnahmen," then he must have perused their papers rather superficially. For Biot ("Mémoire sur la nature de l'air contenu dans la vessie natatoire des Poissons," in *Mém. de phys. et de chim. d. l. soc. d'Arcueil*, T. I., Paris, 1807, pp. 254–281) says, p. 259: "Je n'avois pas . . . les moyens nécessaires pour mesurer exactement la quantité d'acide carbonique, . . . mais je me suis du moins assuré que cette quantité est fort petite." Dr. Schultze doubts the correctness of Biot's observations that the air-bladder in Fishes captured in the sea at a deep level contains great quantities of oxygen. Delaroche and Moreau, too, have proved the correctness of these observations to be beyond all doubt. Moreau (VI., pp. 79–84) has also shown that it is under the influence of the N. vagus that oxygen is received into the air-bladder. Dr. Bohr, Professor of Physiology at our university, has made experiments on the same subject, and has shown "that the formation of gas in the air-bladder is a true secretion of a highly oxygenated gaseous mixture, and that the secretion is so far under the control of the nervous system that it fails when the branches of the vagus which supply the air-bladder are cut" (*Jour. of Physiology*, vol. xv., No. 6, 1893, pp. 494–500).

lung in these animals is not respiratory. But what, in this case, we do not know, is the operation carried on in the capillaries in the recording section of the lung, whereas that which we do know is, that the lung in Snakes is an organ of respiration, *i.e.*, it is by turns receiving and expulsing the air. And we have not the slightest reason for doubting that the atmospheric air reaches the hinder part of the lung, if by no other means, at any rate by diffusion, by which means the air reaches into the bronchioli respiratorii and the alveoli pneumonales in the Mammalia. If we suppose that the hinder part of the lung in Snakes is not respiratory, we have simply turned things upside down; the conclusion being drawn from what was unknown to and against what is known: and yet it has given no offence. The very same method has been adopted with respect to the pseudobranchia and opercular gills in Fishes. We continually meet with the statement that when these organs receive venous blood their function is respiratory, but when they receive blood which has passed through the gill their function is not respiratory. And this theory is still maintained though there is not the slightest reason to suppose that, even in the latter case, the function of these organs should be another than that of the gills themselves with regard to the diosmotical relations. It is of some interest to see that none of the authors, who have supposed the air-bladder in some Fish to be a lung, has cared to get a notion of the mechanism necessary for the renewal of the air.

On account of the structure of the air-bladder and the relations of its arteries and veins, Sir Richard Owen judged the air-bladder in Protopterus to be an organ of respiration. Peters,[1] who has given the fullest account of the anatomy of this fish, gives a copious description of the ramification of the blood-vessels to the gills and the air-bladder, and says as follows (p. 17):—

"Im Ursprung unterscheidet sich die Lungenarterie, wie man sieht, nicht wesentlich von andern Körperarterien, die aus der Aorta Blut erhalten, und dies könnte es zweifelhaft machen, ob die Lungen des Lepidosiren [Protopterus] wirklich Lungen sind; diese Natur

[1] Peters: Ueber einen dem Lepidosiren annectens ähnlichen Fisch von Quellimane (*Archiv f. Anat. u. Physiol.*, Berlin, 1845, p. 1).

wird aber bewiesen theils durch die directe Einmündung der Lungenvene ins Herz, theils und noch bestimmter [dadurch] dass aus den Aesten des Truncus arteriosus schon Körperarterien entspringen, nähmlich die oben angezeigten." But afterwards, when he had an opportunity of dissecting the living Fish, he already began to doubt, and leaned to the opposite opinion, saying :[1]—" Dass die lungenähnliche Schwimmblase, ungeachtet des besonderen Eintritts ihrer Vene in das Atrium des Herzens, dennoch kaum als Lunge fungirt, scheint mir daraus hervorzugehen, dass ich an dem lebenden Thiere keinen Unterschied in der Färbung zwischen ihrem Blute und der der Körpervene bemerken konnte."

As to the habits of this animal, we know[2] that it becomes torpid during the dry season, like a fairly considerable number of tropical fishes, as in northern countries some fishes pass the cold season immersed in the mud, in a state of torpor; that it takes in atmospheric air (" occasionally, but at uncertain periods," according to Gray—" Anfangs . . . alle 4 bis 5 Minuten." according to MacDonnell). Where the air it has taken in is respirated, is unknown; the animal appears to swallow it and to expel it again through the mouth; and that it produces sounds: " Merkwürdig war mir," says MacDonnell, " dass es von dem Moment an, da ich es in das Wasser gesetzt hatte, aufhörte Töne von sich zu geben, selbst wenn man es aus dem Wasser herausnahm."

When Dr. Günther made known to the scientific world the Australian Ceratodus, which is so curious in many respects, nothing was known of its habits but what was stated in the passage quoted below. According to his observations, the air-bladder—or, as it is called by Dr Günther, the " lung"—gives off blood to the heart, and one of its arteries can be injected from the arteria cœliaca, while no direct arterial connection exists between the air-bladder and the arcus aortæ, as in Lepidosiren. As to the manner in which Ceratodus is respiring, Dr. Günther proposed[3] the following hypothesis, exclusively based on the anatomical relations:—

[1] Peters: Reise nach Mozambique, IV. Berlin, 1868. *Flussfische*, p. 5.

[2] Peters, *l.c.*—Gray, J. E.: Observations on a living African Lepidosiren in the Crystal Palace (*Proc. of the Zool. Soc.*, London, 1856, p. 343–48).—MacDonnell, R.: Notiz über Lepidosiren annectens (*Zeitschr. f. wiss Zool.*, X., 1860, p. 409–11).—Duméril, A.: Observations sur des Lépidosiréniens (*Compt. rend. d. l'Acad. d. Sci.*, T. LXII. Paris, 1866, p. 97).

[3] Günther, Albert: Description of Ceratodus, . . . (*Phil. Trans. Roy. Soc.*, London, 1871, Pt. II., p. 511–571, p. 542).

"I think it much more probable that this animal rises now and then to the surface of the water in order to fill its lung with air, and then descends again until the air is so much deoxygenised as to render a renewal of it necessary. The Fish is said to make a grunting noise, which may be heard at night for some distance. This noise may be produced by the passage of the air through the œsophagus,[1] when it is expelled for the purpose of renewal. *From the perfect development of the gills we can hardly doubt that, when the fish is in water of normal composition, and sufficiently pure to yield the necessary supply of oxygen, these organs are sufficient for the purpose of breathing, that the respiratory function rests with them alone*, and that the lung receives arterial blood, returning venous blood, like all the other organs of the body. *But when the Fish is compelled to sojourn in thick, muddy water, charged with gases, which are the product of decomposing organic matter*[2] (and this must be the case very frequently during the droughts which annually exhaust the creeks of tropical Australia), *it commences to breathe air with its lung in the way indicated above.* Under this condition the pulmonary vein carries purely arterial blood to the heart, where it is mixed with venous blood and distributed to the various organs of the body. *If the medium in which the Fish happens to be is perfectly unfit for breathing, the gills cease to have any function;* if only in a less degree, the gills may still continue to assist in respiration. Ceratodus, in fact [in fact? !], can breathe by either gills or *lungs alone*,[3] or by both simultaneously."

What is the foundation of the suggestion propounded by Dr. Günther? It is true, he does not tell us so himself, but it is obvious that it is founded on two facts—that the air-bladder is cellular,[4] and that it sends its blood to the atrium of the heart;

[1] In these words the suggestion propounded by Joh. Müller (VII.) is seen to reappear.

[2] But if so, the Fish would, I think, nevertheless be lost, even if it were able to continue the respiration. While I stayed at Rio Paraguay a most extraordinary inundation took place; at that time it was quite a common view to see dead or dying Fishes near the riverside—in the midst of the stream I never saw any. That they had been poisoned by products of decomposition of putrefying organic matter, I could not doubt. Such matters are likely to be absorbed through the skin, a circumstance that Dr. Günther seems to have quite overlooked. That the lateral line serves to inform the Fish of the nature of the water, is no mere conjecture; that it is at least partly an organ of taste, is most certainly proved.

[3] This statement does not, however, agree too well with another passage of the author (p. 541): "the terminal branches of both arteries and veins [of the air-bladder] are rather wide, and can be injected with great facility."

[4] The remarkably well-drawn figure of the air-bladder in Dr. Günther's work (Pl. XXXVIII. fig. 2) shows me a structure which bears the greatest resemblance to air-bladders, that are sound-producing organs. But for the above-mentioned reason, I dare not—even as supposition—advance the opinion that this is the organ by which the animal produces the sounds which it is known to emit.

perhaps his suggestion that the air-bladder acts as an organ of respiration is right, perhaps it is wrong. I observe that Dr. Günther does not refer to the highly interesting and excellent investigations of Day (X*a*),[1] published three years before, on air-breathing fishes of India.

As to the biology of Ceratodus, we have, as far as I know, only a short report in a letter from E. Pierson Ramsay,[2] who kept some living specimens in the Australian museum at Sydney. And his report does not prove its breathing atmospheric air; for though he kept them "in a large tank," he does not say a word of their taking in air, but "when it rests on the bottom of the tank the pectorals are placed at nearly right angles to the body, the posterior fins lying parallel to the tail. If not disturbed they will remain in this position for hours, and only when stirred up think it necessary to use their fins and tail at all." For though it was "winter time and very cold," this behaviour offers a complete contrast to the proceeding of real air-breathing fishes, with regard to which Day says (X*a*, p. 275):—". . . . . the purely water-breathers, if the term is admissible, can live without rising to the surface, unless under peculiar circumstances, whilst the compound breathers, as already mentioned, expire in a longer or shorter period if unable to reach the atmospheric air," whilst in another place (X*b*., p. 205)[3] he says:—"Of course under certain *abnormal* conditions, all species [of Fishes] rise to the surface, as I have already pointed out." I have lately seen in *Zoologischer Anzeiger* a notice on a work of R. Semon, "Zoologische Forschungsreise in Australien und dem Malayischen Archipel," the first volume of which work deals with Ceratodus. After the few words, added as a summary, the notice goes on to say:—"Das Tier atmet einmal in 30–40 Minuten." The work itself I have not seen as yet; it is to be hoped that the author, who has had an opportunity of studying the animal in its native habitat, has been able to give conclusive information whether the air taken in by the animal is respired in the air-

[1] X*a*: Day, Fr., "Observations on some of the Freshwater Fishes of India" (*Proc. of the Zool. Soc.*, London, 1868, pp. 274–288).

[2] *Proc. of the Zool. Soc.*, London, 1876, pp. 698–99.

[3] X*b*: Day, Fr., "On Amphibious and Migratory Fishes of Asia" (*Journ. of the Linn. Soc.*, London, vol. VIII., 1878, pp. 198–215).

bladder, or, as is the case in so many other Fishes, in the intestines, or in some other organ.

Posterior to Dr. Günther, a German author, Dr. Boas,[1] has found that the air-bladder in Ceratodus receives blood from the 4th gill-vein. Why the author considers the air-bladder to be a "lung" he does not tell us. But to him the circulation of blood in the organ cannot have been conclusive, as he regards the air-bladder as a lung, not only in Ceratodus and Protopterus, but also in Amia,[2] Lepidosteus,[3] and Polypterus,[4] although these fishes afford a striking contrast in that respect: for in some (in Ceratodus, according to Boas, and in Polypterus) the organ receives its blood from one pair, in others (Amia) from two pair of gill-veins; in others (Lepidosteus) from the aorta; and it returns it, now to the atrium of the heart (Ceratodus and Protopterus), now again to the kidneys (Lepidosteus), or the liver (Polypterus), or to the veins of the body (Amia, according to Franque). Accordingly, as it cannot be the relations of the blood-vessels that have determined the suggestion of this author, it must have been the circumstance that in all these forms the air-bladder is very cellular; thus his view is essentially older even than Joh. Müller.

Now, I am well aware that most readers will shake their heads at my presuming to question the accuracy of the generally adopted opinion that the "Dipnoi" respire by means of their air-bladder. But in order to point out how difficult it is to get a thorough knowledge of the function of an organ by mere

[1] Boas, J. E. V., Ueber Herz und Arterienbogen bei Ceratodus und Protopterus, *Morphol. Jahrbuch*, VI., 1880, p. 321–354.

[2] This animal is well known to take in atmospheric air (Wilder, B. G., in *Proc. Amer. Asso. Adv. Sci.*, 1875, Salem, 1876, p. 151; *ibid.*, 1877, p. 306–313); "Aereal Respiration in the Mud-Fish," in *Proc. Bost. Soc. Nat. Hist.*, XIX., 1878, p. 337; but we ignore by which organ it respires the air.

[3] Poey, F. (Memorias sobre la historia natural de isla de Cuba, T. II., 1856–58, p. 69), and B. G. Wilder (in his first quoted paper), have found that also this Fish takes in atmospheric air; but it is unknown in which organ it is respired. The observation of Poey is incorrectly referred by A. Duméril (*Hist. Nat. de Poissons*, T. II., 1870, p. 300).

[4] In a later paper (Ueber den conus arteriosus und die Arterienbogen der Amphibien. In *Morphol. Jahrbuch*, VII., 1882, pp. 488–572) Dr Boas has not included Polypterus among the Fishes which he supposes to breathe by means of a "lung." The reason (which the author has forgotten to tell his readers) is, that I myself informed him personally of the above-mentioned features of the habits of this Fish.

anatomical examinations, even if only mechanical principles are in question, I shall recall to the memory of my readers how the theory of Borelli as to the air-bladder as a hydrostatic apparatus was considered a fact beyond all contradiction, and yet it was crushed when put to the first[1] serious experimental test. Nay, even a thing so plain in appearance as the effect produced on an organ by the contraction of a muscle may be misinterpreted: not only Bridge and Haddon, but even a prominent author like Joh. Müller has been of opinion that the powerful extrinsic muscles of the air-bladder in the Pimelodina would by their contraction effect a compression of the organ, while the fact is that they effect an expansion, be it even momentary, of the said organ. And I do not doubt but that a reader who is not versed in the literature in question would, in perusing the physiological section of the work of Professors Bridge and Haddon, be filled with admiration at the acuteness and close reasoning displayed—and yet scarcely one passage is correct, because they have not examined the said organs in living specimens, and because they had but an insufficient knowledge of the literature in which are deposited the results of that kind of investigation.

It is worth remembering that in the air-breathing fishes, in which the matter is *well* known, it is not in the air-bladder that the respiration of the inhaled air takes place. Not to mention some of our European Cyprinoidæ, *e.g.*, *Carassius vulgaris*, which in the summer time, when the water is getting deficient in oxygen (if they live in smaller ponds), try to remedy this want by letting the atmospheric air pass, together with the water, over their gills, it is well known in the European species of the Cobitini that the respiration of atmospheric air, which frequently takes place when these fishes are chased out of the mud, where they use to live almost without stirring, though now and again, with long intervals however, they resort to the surface to take in atmospheric air, is brought about by the intestine.[2] The

[1] Valenciennes (XV., vol. xvi., 1842, pp. 14–16) had made experiments to empty the air-bladder of air in *Gobio fluviatilis* and he had seen it "très doucement" filled with air in the course of some hours, without the animal taking in atmospheric air. But Valenciennes did not see the bearing of his own observation.

[2] Erman, in his excellent paper, Untersuchungen über das Gas in der Schwimm-

same fact has been established, according to Jobert,[1] in Hypostomus sp. (XI*b*), Callichthys asper (XI*a*), Doras sp. (XI*b*), and Loricaria sp. (XI*a*), which Fishes cross the land to reach other waters, when their former dwelling-places are growing short of water. In his interesting investigations on several air-breathing Fishes of India, Day (X*a* and X*b*) has proved that the respiration of the atmospheric air is brought about in the labyrinthiform part of the gill-cavity in Polyacanthus, Osphromenus, Trichogaster, Ophiocephalus, and Rhyncobdella. The same author has pointed out that the air is respired in the accessory gill-cavity of Clarias,[2] Saccobranchus, and Amphipnous. The existence of an accessory "gill-snail" (Kiemensschnecke) has been proved by Hyrtl[3] in Heterotis Ehrenbergii, Chanos ("Lutodeira chanos"), Meletta thryssa, Chatoessus jacunda, Gonostoma Javanicum, Clupanodon aureus, Pellona Lechenaultii, and Hyodon claudalus, and an organ of a similar structure has been found by Kner[4] in Cœnotropus labyrinthicus, Curimatus vittatus, and C. cyprinoides. Most probably this organ is an air-breathing organ; however, before the year 1884, no physiological proof existed of this being the case.

When I said above that an air-bladder without a pneumatic duct, or with a long, narrow, and thin-walled pneumatic duct, may be determined as a sound-producing organ (according to our present knowledge), when furnished with extrinsic or intrinsic muscles, especially when its cavity is divided into inter-com-

blase der Fische, und über die Mitwirkung des Darmkanals zum Respirationsgeschäfte bei der Fischart Cobitis fossilis (*Gilbert Annalen der Physik.*, XXX., Halle, 1808, pp. 113–161).

[1] XI*a*: Jobert, Recherches pour servir à l'histoire de la respiration chez les Poissons (*Ann. d. Sci. Nat.*, 6 Sér., T. V., Paris, 1877, Art. No. 8).—XI*b*: Jobert, Recherches anatomiques et physiologiques pour servir à l'histoire de la respiration chez les Poissons (*ibid.*, 6 Sér., T. VII., Paris, 1878, Art. No. 5).

[2] I myself, who did not then know of the examinations of Day, have made the same at least almost evident with regard to Clarias macracanthus from the Nile (Om Aandedrœttet hos Clarias [On the Respiration in Cl.]. In *Naturhistorisk Tidskrift*, 3 R., Bd. XIII., Kjöbenhavn, 1883, p. 396–414).—What I there have said on the nature of the gill-rakers of Clarias is wrong.

[3] Hyrtl, J., Beitrag zur Anatomie von Heterotis Ehrenbergii (*Denkschr. d. k. Akad. d. Wiss. in Wien*, Bd. VIII., 1854, p. 74).—Hyrtl, J., Ueber besondere Eigenthümlichkeiten der Kiemen und des Skelette, und über das epigonale Kiemenorgan von Lutodeira (*ibid.*, Bd. XXI., 1862).

[4] Kner, R., Ueber Kiemen-Anhänge bei Characinen (*Ver. d. Zool-bot. Ges. in Wien*, 1861, p. 189).

municating chambers, I must point out that some naturalists have succeeded in proving, with regard to some Fishes, that the air-bladder serves to produce tones, even if it is *not* provided with special muscles. This fact has been proved by Dufossé, by means of vivisection of the animals, in *Peristedion cataphractum Trigla lyra, Hippocampus brevirostris, Sciæna aquila*, and *Umbrina cirrhosa*. In these Fishes the air-bladder sounds during the activity of the muscles, with the fascia of which the walls of the air-bladder are intimately connected. In these Fishes the conditions, at least according to the indications of Dufossé, are such that it would hardly have been possible to any one, by a mere anatomical examination, to recognise the air-bladder as a sound-producing organ. But, on the strength of Dufossé's physiological examinations, I am of opinion that the air-bladder has the same function in *Triacanthus brevirostris* and *Tr. biaculeatus*. In the following Fishes I have succeeded, by a mere anatomical examination, in recognising the air-bladder as a sound-producing organ, though it is not provided with special muscles: *Tetrodon fahaka, Balistes vetula, Monacanthus pardalis*, and *Holocentrum sogho*, in which Fishes the walls of the air-bladder are acted on in a somewhat different way by the muscles leading to the "coracoideum" (Cuv.). Finally, Professor Möbius [1] has recognised the air-bladder of *Balistes aculeatus* as a sound-producing organ, likewise employed in sounding under the action of muscles which lead to the same bone ("Postclaviculare"). And while I had arrived at the said result through anatomical examination alone with regard to the above-mentioned species of this genus, Professor Möbius had the opportunity to observe in *B. aculeatus*, in the living animal, "while the fish was drumming, a quick raising and sinking of a small spot of the skin," which spot proved by the following anatomical examination to be in immediate contact with part of the wall of the air-bladder.

[1] XII: Möbius, K., Balistes aculeatus, ein trommelnder Fisch. (*Sitzber. d. Akad. d. Wiss.*, Berlin, Bd. XLVI., 1889, p. 999–1006). Zacharias, Otto, "Trommelnde Fische" (I have but seen a copy of this short paper, four pages) contains no independent investigations, but is only a popular report of the paper of Möbius.

(*To be continued.*)

Notices of New Books.

Ergebnisse naturwissenschaftlicher Forschungen auf Ceylon in den Jahren, 1884–86, von Dr Paul Sarasin und Dr Fritz Sarasin. Dritter band. *Die Weddas von Ceylon und die sie umgebenden völkerschaften, ein versuch, die in der Phylogenie des Menschen ruhenden Räthsel der Lösung näher zu bringen.* Wiesbaden, 1893.

In this magnificent work, consisting of a large quarto volume of 599 pages of text, with numerous photogravures, cuts, and tables, and a corresponding atlas containing 84 splendid plates with 188 figures, the brothers Sarasin have produced the most complete treatise on the people of Ceylon which has yet been published. Although the attention of the authors was especially directed to the interesting aboriginal race termed Wedda or Veddah, much information is also given on the Tamils, Singhalese, Rodiyes, and the Indo-Arabians or Moormen.

In the course of their inquiries they have gone with care into the physical anthropology of the people. The external characters and proportions of the body, the colour of the skin, eyes, and hair, the shape of the nose, eyes, lips, and jaws, have been examined. The craniology and general osteology of the Weddas, Tamils, and Singhalese have been described with much detail, and a comparative examination of the external characters and osteology of these different peoples has been made. The general conclusion to which the authors have arrived is that the Tamils are more nearly allied to the Weddas than are the Singhalese. They regard the Dravidians generally as further stages of development of Wedda forms. The Singhalese, on the other hand, appear to have a stronger intermixture of Aryan blood than the Tamils, which indeed constitutes the essential difference between them. A comparison is also instituted between these Ceylonese races and races external to the island.

After having disposed of the physical characters and ethnological relations of the people, the authors devote several chapters to the consideration of the mode of life of the Weddas,—their habitations, clothing, food, domestic animals, instruments, sexual relations, sociology, religion, language, songs, poetry, and character.

From the figures in the atlas an excellent conception may be obtained of the colour of the skin, the external characters of the body, many of the habits of life, the characters of the skull and other bones of the skeleton.

So complete is the work, and so unsparing have the authors been in their labour and in the cost of production, that it has assumed a monumental aspect. No one can in the future treat of Ceylon or its people without constant reference to the researches of the brothers Sarasin.

SOME RECENT ANTHROPOLOGICAL MEMOIRS.

1. *The Ethnography of the Aran Islands, County Galway.* By Prof. A. C. Haddon and Dr C. R. Browne. Dublin, 1893. *Proc. Royal Irish Academy*, Dec. 12, 1892.
2. *Studies in Irish Craniology.* The Aran Islands, County Galway. By Prof. A. C. Haddon. Dublin, 1893. *Proc. Royal Irish Academy*, Dec. 12, 1892.
3. *On some Crania from Tipperary.* By Dr C. R. Browne. Dublin, 1893. *Proc. Royal Irish Academy*, Feb. 27, 1893.
4. *The Ethnography of Inishbofin and Inishshark, County Galway.* By Dr C. R. Browne. Dublin, 1894. *Proc. Royal Irish Academy*, Nov. 30, 1893.
5. *The New Hebrideans.* By the Rev. J. H. Lawrie. *Scottish Geographical Magazine*, June 1892.
6. *The Nasal Index compared upon the Head and Skull, with notes upon the nasal bones and anterior nasal aperture.* By Prof. Havelock Charles. *Journal Asiatic Society of Bengal*, vol. lxiii. part iii. No. 1, 1894.
7. *Remarks on the Morphology of the lumbar, sacral, and caudal regions of the Panjabi.* By Prof. Havelock Charles. *Scientific Memoirs by Medical Officers of the Army of India*, part viii. Calcutta, 1894.
8. *Contributions to the Osteology of the Aborigines of New Zealand and the Chatham Islands.* By Prof. John H. Scott. *Transactions of New Zealand Institute*, vol. xxvi., 1893.
9. *Zur Physischen Anthropologie der Feuerländer.* By Dr Rudolf Martin. Brunswick, 1893. *Archiv für Anthropologie*, Bd. xxii. Heft 3.
10. *Le Varietà Umane della Melanesia.* Memoria prima, by Prof. G. Sergi. Rome. *Bollettino della R. Accad. Medica di Roma.* Anno xviii. Fasc. ii.
11. *Atti della Società Romana di Antropologia.* Vol. i. Fasc. i. Roma, 1893.
12. *L'Epoque Eburnéenne et les Races Humaines de la période Glyptique.* By Ed. Piette. Saint-Quentin, 1894.

13. *Recherches sur les Ossements humains anciens et préhistoriques en vue de la reconstitution de la taille.* By Dr J. Rahon. Paris, 1893. *Mémoires de la Soc. d'Anthropologie de Paris*, 2nd series, vol. iv.

14. *Description of Two Skulls from Nagyr. Journ. Anth. Inst.*, Nov. 1893. *A Critical Study of the Collection of Crania of Aboriginal Australians in the Cambridge University Museum. Journ. Anth. Inst.*, May 1894. By W. L. H. Duckworth.

15. *Étude sur les variations morphologiques du corps du Fémur dans l'espèce humaine.* By L. Manouvrier. Paris, 1893.

16. *Der Bau des Menschen als zeugniss für seine Vergangenheit.* By Prof. R. Wiedersheim. Freiburg, 1893.

UNDER the auspices of the Anthropometric Committee of the Royal Irish Academy a series of studies in Irish Ethnography has been commenced, and the memoirs (1, 2, 3, 4) by Prof. Haddon and Dr C. R. Browne, which head our list, are the first-fruits of the peripatetic work which those associated with the Anthropological Laboratory instituted by Prof. D. Cunningham in Trinity College, Dublin, have conducted. The plan followed by the authors has been to reside for a time in the district the people of which have been under investigation, to note its physiography, anthropography, the physical characters, ethnology, and craniology of the people, the vital statistics, sociology, folklore, archæology, and history. It will be seen that the plan pursued is very complete, and if carried out systematically in the various parts of Ireland will bring together a body of most valuable information, which will enable a much more precise conception to be obtained of the distribution of the races by which Ireland has been populated than has yet been attempted.

The Rev. J. H. Lawrie, of Aneityum, gives in No. 5 an account of the people of the New Hebrides, the great bulk of whom belong to the Papuan race. On some of the smaller islands he thinks there has been an admixture of Malayan blood. The people do not all speak the same language: on Tanna, for example, three languages are spoken; on Malekula, as many as five.

In Nos. 6 and 7, Prof. Havelock Charles, who has contributed several interesting anthropological memoirs to this *Journal*, continues his inquiries. In No. 6 he compares in several of the races of India the height of the nose with the breadth of the antorior nasal aperture, firstly on the head, and then on the skull of the same subject, after the soft parts have been removed. He finds that the long diameter of the nose on the skull is greater than the height of the nose on the head; generally the difference will be about 4 μ in the higher races, probably less in the lower castes. The transverse diameter of the anterior nares in the skull is less than the breadth of the nose on the same head: thus the long diameter is greater in the skull, the trans-

verse diameter is greater in the head. A nasal index calculated from measurements on the head will not be so high as one calculated from the skulls of the same race.

In No. 7, Prof. Charles records the measurements of the lumbar, sacral, and coccygeal vertebræ in the spines of the Panjabi, and compares his observations with those made by Sir William Turner in his memoir in the *Reports of H.M.S. "Challenger."* In the Panjabi the mean collective depth in 28 spines was 113·8 mm. for the anterior surface of the five lumbar vertebræ and 118·3 mm. for the posterior surface, while in Europeans the mean depth of the collective anterior surfaces is 5·6 mm. greater than that of the posterior (Turner). Whilst in Europeans the 5th lumbar is deeper in front than behind, Charles's Table No. 1 shows that in 28 Panjabi skeletons it was thicker behind than in front in 8, equal in 4, and thicker in front than behind in 16. The average general lumbar index for the series was 103·8. The average general lumbar index of 7 spines with the discs in a recent state was 106·8. The average Panjabi sacrum is dolichohieric: the index in 40 males was 99·8, in 7 females 108·4.

No. 8 is an elaborate memoir by Prof. J. H. Scott on the Osteology of the Maori and Moriori people. He has measured 83 Maori skulls, 45 of which belong to a single tribe in the South Island in the provinces of Otago and Canterbury. He compares his measurements with those of Flower on the skulls in the Museum of the Royal College of Surgeons, and of Turner in the Anatomical Museum of the University of Edinburgh. Prof. Scott has examined 50 skulls from the Chatham Islands, 4 of which he believes are Maori rather than Moriori. He recognises two types, the one the prevailing type, large and heavy skulls with prominent parietal eminences, roof-like vertex, pentagonal shape, and low flattened forehead; the other with higher and more rounded forehead, less pentagonal shape, less projecting zygomata, and smaller orbits.

Prof. Scott has measured 13 more or less complete Maori spines and 4 Moriori; 24 Maori pelves and 3 Moriori; and a number of the bones of the limbs. As regards the index of the pelvic brim in the Maori, the average in the male was 86·1, in the female 87·7; they fall, therefore, into the platypellic group of Turner, which is also the case with the Moriori pelves. Measurements of many of the limb bones are also given. The author's investigations on the skeleton have shown that in the Maoris the spine is typically savage in its component parts; the sacrum is platyhieric, almost subplatyhieric; the upper limb is mesatikerkic; the lower limb, though brachyknemic, is on the verge of dolichoknemic; the tibia is platyknemic. He concludes that the Maori race is mixed, both a Melanesian and Polynesian type being found.

The physical anthropology of the natives of Tierra del Fuego is described at considerable length (No. 9) by Dr Rudolf Martin. The material at his disposal consisted of five complete skeletons of the

Alakaluf tribe, and several specimens of the internal organs. The skeletons had belonged to the members of a troop of Fuegians who visited Europe in 1881, and the most of whom died.

Prof. Sergi communicates (No. 10) a first memoir on the Melanesians. He describes, figures and gives the measurements of a number of crania in which he recognises varieties of form, and assigns to each variety a descriptive term. He considers that the Papuans are made up of many morphological varieties.

Prof. Sergi has in No. 11 a memoir on the principles and method of classification of the races of men. He describes and figures in outline numerous varieties in form of the human skull, and suggests a nomenclature for them. In the same *Atti* are papers by Prof. Moschen on the stature of the people of Trentino, and by Dr Mingazzini on the craniology of the insane.

The glyptic period is divided by M. Piette (No. 12) into two epochs—the Ivory or Elephant, and the Reindeer.

Dr Rahon's memoir (No. 13) is a careful inquiry into the height of ancient and prehistoric races, based on measurements of the long bones of the limbs. The neolithic people, notwithstanding many variations, have almost constantly a mean height below the present mean height. The protohistoric Gauls, Franks, Burgundians, and Merovingians had a height greater than that of the modern French.

In No. 14, Mr Duckworth describes two skulls from the Central Asian State, Nagyr. They are dolichocephalic, the length-breadth indices being 69·9 and 68·2. In his second memoir Mr Duckworth analyses the characters of the aboriginal Australian crania in the Cambridge University Museum. The characters of the South Australian crania are critically examined, and the provisional conclusion is reached that the dolicho-platycephalic individuals form only a section of the natives of South Australia.

In the same number of the *Journal of the Anthropological Institute* Messrs R. Etheridge, jun., and P. W. Bassett-Smith contribute papers on the Australian aborigines, and Lieut. Boyle Somerville furnishes anthropological notes on the New Hebrides.

M. Manouvrier publishes (No. 15) a second memoir on the form of the human femur. His attention is especially directed to *le pilastre femoral*, and to the flattening of the upper part of the femoral shaft, originally described by W. Turner in the Maori and other femora of savage people, a condition which Manouvrier has named *platymèrie*.

Prof. Wiedersheim's work (No. 16) gives, in a compact form, the most important variations in human structure, which most closely approximate to characters normally found in lower vertebrates.

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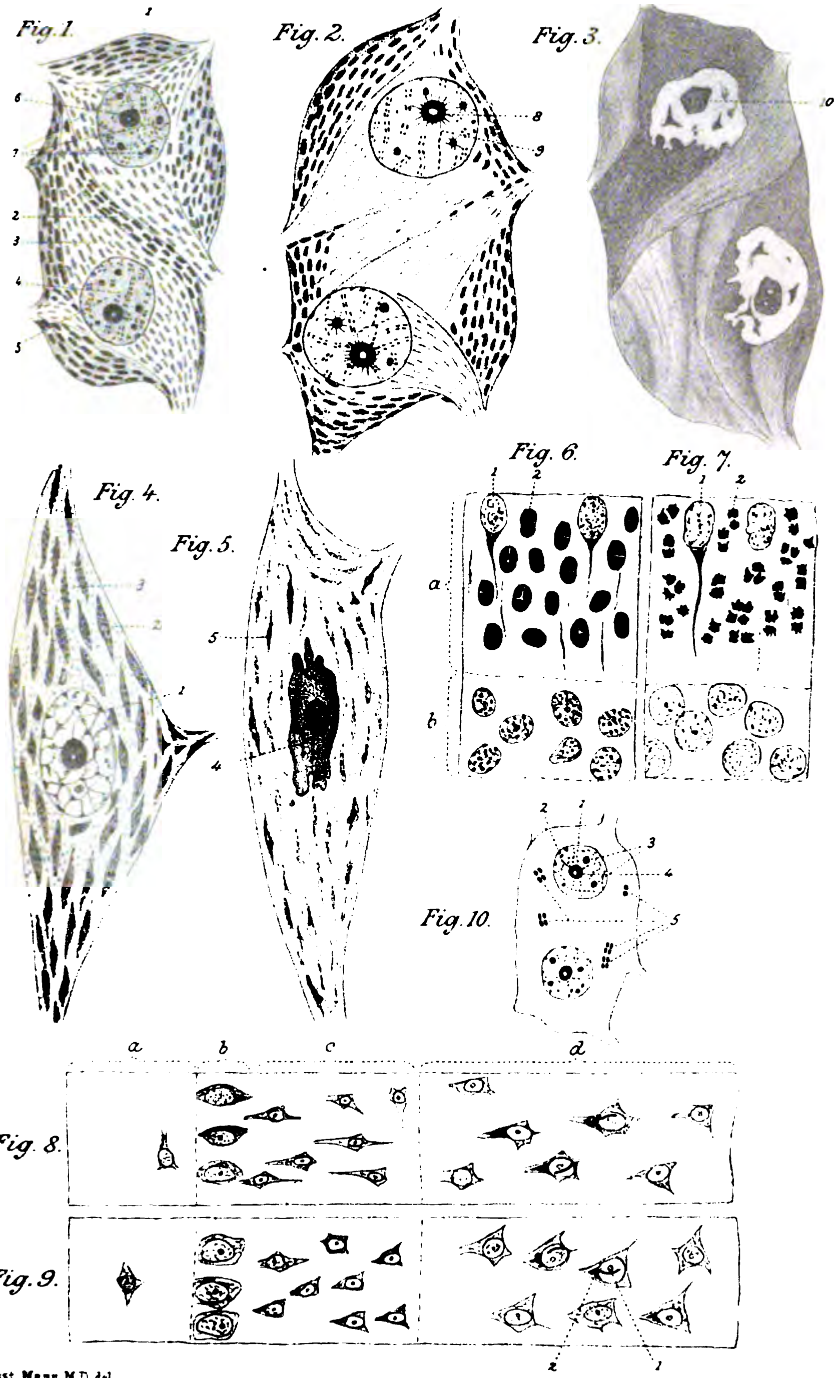

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Journal of Anatomy and Physiology.

ON THE CARPUS OF THE GREENLAND RIGHT WHALE (*Balæna mysticetus*) AND OF FIN-WHALES. By JOHN STRUTHERS, M.D., LL.D. (PLATES II., III., and IV.).

ONLY a very short notice has yet appeared of the demonstration I gave at the meeting of the *British Association* in 1885, "On the Carpal Bones in various Cetaceans" (Report, 1885, p. 1056), in which I laid before the Association the dissections I had made, from time to time during the preceding fifteen years, of these parts in Mysticetus, Megaptera, Balænoptera musculus, B. borealis and B. rostrata; and, among the toothed whales, in Hyperoodon, Beluga, Globicephalus and Narwhal. I propose in this paper to consider these parts in whale-bone whales only, more especially in *Mysticetus* and in *B. musculus*, reserving the account of my dissections in toothed whales for a subsequent communication. Although my primary object was to examine the carpus, I embraced the opportunities of observing other cartilages and bones in the pectoral limb of Mysticetus, and I add some notes of these in comparison with the same parts in the great Fin-whale above mentioned.

I may here say, in advance, that the interest of this inquiry depends mainly on the consideration that these carpal cartilages, more or less ossified, in the cetaceans here dealt with, are, as will appear below, to be interpreted as rudimentary structures. I mean that their occurrence as separate bodies without movement on each other, corresponding to the wrist bones of active-handed animals, can be reasonably interpreted only on the far-reaching hypothesis of the descent so-called of species, with modification, from pre-existing species in which these bones had their

uses as separate bodies. Before such a conclusion is warranted in any case the parts concerned must be subjected to the ordeal of a severely critical anatomical examination. Hence the fulness and seeming detail with which the subject is treated in this communication. From the point of view of that interpretation we are, further, prepared to expect to meet with variations in the same species such as those noticed below.

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I. THE CARPUS IN MYSTICETUS.

Specimens examined.—The paddles dissected were those of a 48-feet-long female, which may be considered to have been full-grown or nearly so, and the right paddle of a 35-feet-long male, which may be considered as two-thirds grown and termed adolescent. They were obtained from Davis' Straits in 1873–74, and were the specimens from which I gave an account of

the finger-muscles in Mysticetus in this *Journal* (vol. xii., 1878).[1]

Figure 1 represents the paddle (less the scapula which I did not obtain) of the adult female; figure 2 that of the adolescent male; figures 3, 4, and 5 are *sections*, figure 3 of the *left* carpus and neighbouring parts of the adult female, figure 4 of the *right* carpus of the same, figure 5 of the right carpus of the adolescent male. The sections show the variations in the number and extent of the carpal ossifications in each, to be commented on below. It will facilitate if the explanation of the plates is read now.

Surface appearances.—The perichondrium of the carpus is about $\frac{1}{8}$ inch thick, about half the thickness of the periosteum on the forearm. It is very adherent and numerous large blood-vessels are seen to pass between it and the carpal cartilages. When the perichondrium is detached, strongly marked furrows are seen, marking off the outlines of the carpal cartilages. These furrows, with their sloping sides, are about $\frac{1}{8}$ inch wide, and are closed everywhere by fibrous tissue uniting the cartilages across the bottom of the furrows.

Do the furrows on the palmar and dorsal surfaces correspond? To determine this I had made a table of longitudinal and transverse measurements on each surface, and, on running the eye along the columns, they are seen to correspond exactly and to correspond also to the measurements taken at the fibrous sutures as seen in section; that is, the lines of articulation go straight through and through. This, indeed, is sufficiently apparent to the eye on laying the dorsum of one carpus alongside the palmar view of the other; or, more strictly, in the same carpus after section, by comparing the dorsal and palmar views with the other half of the section.

The ossifications may not show themselves on the surface. In the adolescent male none of them had reached the surface. An ossification may show itself on one surface but not on the other, and those seen on the surfaces do not indicate the size in the interior. Sections must be made to ascertain whether ossification

[1] As my papers on the anatomy of the Cetacea have all appeared in this *Journal*, and as I must occasionally refer to them, it will suffice to give as references simply the date and page with *loc. cit.*

is present, and its full extent. When this is not allowed, numerous piercings with a long needle may be tried.

General appearances on horizontal section.—There are no synovial cavities anywhere in or near the carpus, neither between the carpal cartilages, nor at the wrist joint, nor at the carpo-metacarpal joints. Narrow lines, about $\frac{1}{12}$ inch or finer, of fibrous suture mark off the cartilages from each other. The uniting fibrous tissue is soft but firm, resisting the end of the handle of the scalpel. The fibrous union goes through and through, occupying the whole depth of the contiguous surfaces, which averages about four inches in the adult. Extremely little movement can be made of the cartilages on each other. As the contiguous surfaces are rectangular to the surface there can be no oblique gliding movement.

When the section has been allowed to become a little dried, these fibrous sutures stand up, $\frac{1}{8}$ to $\frac{1}{6}$ inch thick, like the edges of shallow cups, inclosing the cartilaginous areæ, but when these raised edges are sliced off, the true thickness of the narrow suture, about $\frac{1}{12}$ inch, is seen through and through in the whole depth. At the angles where three sutures meet, the fibrous tissue is broadened into a triangular figure, rounding off the angles of the cartilages. At these points it may be $\frac{1}{4}$ inch or more in thickness. The lines of fibrous suture seen in figs. 3, 4 and 5, are represented rather too boldly.

The surface of the cartilaginous masses, in the sections, shows the numerous apertures and groovings of large blood channels, surrounded by connective tissue, seen in sections of masses of cartilage in the Cetacea. No blood-vessels were seen to pass through the fibrous sutures from one cartilage to another. The carpal ossifications, and the neighbouring ossified epiphyses of the radius and ulna, present close cancellous structure, the pits longitudinally elliptical, with numerous apertures for blood-vessels.

(A) *Carpal Cartilages in the 48-feet-long female Mysticetus.* (Figs. 3 and 4.)

The bones present, in the cartilaginous condition, are five in *number*; in the first row, radiale, intermedium, ulnare, pisiform;

for the second row, only one disto-carpal, situated to the radial side, supporting digits III and II and, in part, digit I. The ossifications are, in the left carpus (fig. 3), in the intermedium and ulnare; in the right carpus (fig. 4) in these and in the disto-carpal.

TABLE I.—*Giving, in inches, the transverse and longitudinal measurements of the carpal cartilages and bones in the Younger and in the Adult Mysticetus as seen on Section, and of the ossifications appearing on the palmar and dorsal surfaces. The transverse and longitudinal measurements are placed in the same column, the transverse first.*

Carpal Cartilages and Ossifications in Mysticetus.	Younger Section.		Adult Section.			Bone seen on Surfaces. Adult.			
	Cart.	Bone.	Cart.	Bone.		Palmar.		Dorsal.	
	Right.	Right.	Both.	R.	L.	R.	L.	R.	L.
Radiale, . . .	3¼×?	1⅛×1¼	5×4	..	..	..	..	..	..
Intermedium, . .	4×2¼	1⅝×1½	6×5¾	4½×4½	..	4×4	..	4×3½	..
Ulnare, . . .	4×2½	..	8×6½	4½×4¾	4⅝×5½	4×4½	4×4½	3¾×3½	..
Pisiform, . . .	5½×2¾	..	6⅛×4¾	..	..	..	..	..	..
Disto-carpal, . .	5×1¾	1×½	7¼×5	3¾×2⅞	..	..	..	1¼×⅞	..

The size of the entire carpus was—In the *younger* Mysticetus, breadth, to pisiform 12½ inches, with pisiform 18; length, average, 4½ inches. In the *adult*, breadth, to pisiform 20½ inches, with pisiform 26; length, average, 8 inches; thickness, at the intermedium 4½, at the ulnare 3½. Size of the *bony epiphyses* of radius and ulna, in the adult Mysticetus,—of radius, 8¼ × 2 inches; of ulna, 8¾ × 3.

The following may be noted in regard to the *form* and *articulations* of the carpal cartilages, as shown in the drawings, figs. 3 and 4. Either figure may be referred to as they are quite symmetrical.

1. The *radiale*, entirely cartilaginous; form, triangular; articulations 3 in number, proximally with radius, distally with the disto-carpal and the pollex. Is continuous with the latter on the radial fifth of their relation to each other. On the radial side it forms part of free margin of carpus; on the ulnar side it approaches the intermedium, but their neighbouring angles are merely connected by a fibrous commissure, a thickened part of the fibrous suture where four bones meet. This fibrous commissure, in left carpus ½ inch transversely

by $\frac{1}{4}$ inch longitudinally, in right carpus $\frac{3}{8}$ inch both ways, alone interposed between the radius and the disto-carpal.

2. The *intermedium*, irregularly four-sided; articulations 4 in number, proximally with radius and ulna, twice as much with radius as with ulna, the ascending angle seen to pass considerably (fully $\frac{1}{3}$ the length of the whole cartilage) up between radius and ulna; to ulnar side with ulnare; distally, by its whole breadth, with the disto-carpal.

3. The *ulnare*, square-shaped; articulations 6 in number, proximally with ulna; to radial side with intermedium, and for $\frac{1}{3}$ of its length with the disto-carpal; distally with three digits, V, IV, and III, that with digit V facing obliquely to ulnar side.

The *pisiform*, elongated transversely, tapering to a rounded end and curved with convexity upwards. Upper border shows an angle to which tendon of flexor carpi ulnaris muscle is attached within the ulnar fibrous curtain. Articulations, by the usual fibrous suture 2 in number, with epiphysis of ulna for $3\frac{1}{2}$ inches, and for $2\frac{1}{2}$ inches with digit V. It has no connection with the ulnare, widely separated from it ($1\frac{1}{2}$ inches) by the meeting of the ulna with digit V.

The *disto-carpal*, the only representative of a second carpal row. Neither on the surfaces nor in the depth on successive slicings, is there any trace of subdivision of this great cartilage ($7\frac{1}{4}$ inches by 5). Articulations 6 in number; proximally with radiale, and more largely with intermedium, the peak sent up between these separated from the radius only by the short thick fibrous commissure above mentioned; laterally with ulnare; distally with digits III, II, and I, the articulation with the latter, about 1 inch, facing laterally.

Carpal Ossifications.—As demonstrated by successive slicings, there is no trace of ossification in the radiale or pisiform in either wrist, nor in the disto-carpal of the left carpus. The intermedium and ulnare are largely ossified in both wrists. The shape of the ossification may be said to follow, generally, that of the cartilage, sending out angles towards the angles of the cartilage, but not always. Thus, the right ulnare wants an internal lower angle, interfering there with the symmetry of the right and left, which is otherwise fair in these two bones. The ossification of these two bones, as shown in the figures, is most advanced on the side towards the centre of the carpus. The ossifying sides of all these bones have jagged edges.

The ossification of the right disto-carpal is of medium size ($3\frac{3}{4}$ inches by $2\frac{7}{8}$). It has not as yet followed the shape of the cartilage in detail, but is elongated transversely. Though nearest the radial side of the cartilage, it is so placed as to be equally opposite digits II and III, thus further indicating the

oneness of this disto-carpal cartilage. The failure of ossification in the disto-carpal of the left wrist is not explained by deficient ossification in that wrist generally.

The fact that the ossification of the disto-carpal, the smallest of the ossifications, shows itself to some extent on the dorsal but not on the palmar surface, and the fact, noted below, that in the adolescent Mysticetus the concealed ossicles were considerably nearer the dorsal than the palmar surface, would seem to indicate that ossification advances more towards the dorsal than towards the palmar surface. But the well-ossified bones, the intermedium and ulnare, show rather more on the palmar than on the dorsal surface, as seen in Table I. The two well-ossified bones in the adult are from ½ inch to 1 inch less on the surfaces than at the middle, as seen in the sections.

Metacarpals.—The figures, 3 and 4, show the metacarpal bones with their proximal cartilaginous epiphysis. The whole of digit I, the *pollex*, is formed of one undivided cartilage.

Careful slicing shows no separation into epiphysis and metacarpal body in the pollex of either hand. The single cartilage articulates, proximally, with the radiale for about 4 inches, and is continuous with it to the radial side for 1 inch; laterally, for about 1 inch, with the disto-carpal, and, for about 3 inches, with digit II, completely separated from them by lines of fibrous suture. Beyond this it is prolonged for 3 inches, as a free thumb-like cartilage tapering to a blunt point.

The epiphyses of the four outer metacarpals are likewise distinctly and wholly marked off by fibrous suture from the carpals on which they rest and laterally from each other. Proximally, digit II articulates with the disto-carpal only; digit III with the disto-carpal and a small part of the ulnare; digit V with the ulnare for 5 inches, with the ulna for 1½, and with the pisiform for 2½ inches. All of the metacarpal epiphyses are cartilaginous.

Carpal epiphyses of Radius and Ulna.—The bony epiphyses at the proximal ends of the radius and ulna, and at both ends of the humerus, are completely united to their shafts, from which it may be inferred that the individual was adult; but the bony epiphyses at the carpal ends are still largely cartilaginous. The ossified parts show themselves very little on the palmar and dorsal surfaces, being covered by a very thin layer of cartilage, apt to be removed with the perichondrium. The outlines of these ossifying epiphyses, and of the unossified cartilages, as seen on section, are shown in the figures (figs. 3 and 4).

The bony part of the ulnar epiphysis is larger than that of the radius, a little transversely but decidedly so longitudinally (the ulnar 8¾ inches by 3, the radial 8¼ by 2), although the radius is much the larger bone. Above, the ossifications are close to the shafts and follow the curvatures

of the ends of the shafts. Ossification of the radial epiphysis is seen to be less advanced towards its radial side, which may be related to the non-ossification of the radial carpal bone; and the greater ossification of both epiphyses at their contiguous ends may be related to the more advanced ossification of the intermedium and the ulnare. Considerable projections of the cartilaginous epiphyses are unossified distally; the projection of the ulnar epiphysis supports the pisiform and part of digit V, that of the radial epiphysis meets the upper angle of the disto-carpal, separated only by the fibrous commissure between the radiale and the intermedium. The considerable ascent of the intermedium between the bones of the forearm strikes the eye in examining these parts.

(B) *Differences in the Carpus of the 35-feet-long male Mysticetus.*

Only the right paddle was obtained. The measurements of the carpal cartilages and ossifications are given in the first column of Table I. With the same arrangement, generally, of the carpal cartilages, the differences from the adult afford remarkable instances of variation, in regard to ossifications and in regard to the continuity of cartilages at two places. The differences are as follows, shown in fig. 5 in comparison with figs. 3 and 4.

(1) The three ossifying carpals, in the order of advancement, are the intermedium, radiale, and disto-carpal. Thus, the ulnare, the most largely ossified in both wrists of the adult, is not here ossified at all; the radiale, not ossified in either carpus of the adult, is here ossifying; and the disto-carpal, not ossified in the left carpus of the adult, has begun to ossify.

(2) Still more remarkable is the fact that the pollex, represented in the adult by one undivided cartilage, resting on and partly continuous with the radiale, has here a well-ossified metacarpal, 2½ inches in length, tipped with a terminal cartilage, as shown in the figure. But there is no marking off to distinguish between the radiale and a proximal epiphysis to the pollex metacarpal, either on the surface or as seen in slicing through and through. Whether this ossification in the pollex belongs to sex, is a question these dissections are not sufficient to answer. Along with it we see ossification in the region of the common cartilage that belongs to the radiale. It is interesting to see that the distal marking-off of a radiale from the pollex, ⅘ complete in the adult, has not yet begun in the

adolescent although the radiale is ossifying in the latter and not in the former. In the one, ossification has preceded subdivision of the cartilage, in the other the cartilage is nearly divided while ossification has not begun, if it ever was to take place.

(3) Allied to the fact of the absence of separation between the radiale and the epiphysis of the pollex metacarpal, is the fact that the carpal epiphysis of metacarpal II is only partially distinct from the disto-carpal. On the surface the furrow appears to reach across the whole breadth, more shallow towards the radial side, but, on slicing carefully through and through, the line of separation is seen opposite only the ulnar half of metacarpal II. The fine line of fibrous suture is clearly seen to terminate abruptly at half way across. This cartilage, in part common to the disto-carpal and the epiphysis of digit II, is quite distinct from the cartilage entirely common to the radiale and pollex. The epiphyses of digits III, IV and V are all marked off from the carpus and from each other by distinctly seen lines of fibrous suture.

Minor differences, in regard to articulation, are: (4) Metacarpal III does not articulate with an angular facet of the ulnare, as it does in the adult, kept down, as it were, by the ulnar end of the disto-carpal being relatively larger than it is in the adult. And (5) the disto-carpal and the radius do not nearly meet, being separated by the radiale and intermedium articulating with each other for about $\frac{3}{4}$ inch. This is not owing to the radius but to the disto-carpal not sending a peak upwards as it does in the adult. If figures 4 and 5 are compared, it will be seen that the disto-carpal is, in the adolescent, narrower on its radial half (deducting the part assignable to the epiphysis of digit II) and broader on its ulnar half, than in the adult, a proportion that stands related to these two differences of articulation.

In regard to the *less advanced ossification*, generally, in this Mysticetus, the non-ossification of the carpal epiphyses of the radius and ulna, and the less advanced ossification in those carpals in which ossification exists, is in accordance with the lesser age of the individual. As seen in figure 5, the ossification of the intermedium has begun at the side next the centre of the wrist, and is of an irregularly rounded form, already sending out angles towards the angles of the cartilage. The upward projection of the cartilage between the radius and ulna is not so marked as in the adult. The ossification of the radiale also has begun at the side towards the centre of the wrist, and is an irregularly oval ossicle directed longitudinally. The disto-carpal ossification is yet but a small ovoid nodule; is, like its cartilage, directed transversely, and has begun at about the centre of its cartilage, opposite the radial side of the metacarpal III.

As noted above, none of the ossifications appeared on the surface. The thickness of the entire carpus was, at the intermedium $2\frac{1}{2}$ inches, at the ulnare 2, at the radiale $1\frac{1}{2}$. The bones in this adolescent subject were soonest reached from the dorsal surface. The depths of the intermedium, radiale, and disto-carpal from the surfaces were, respectively, from the *palmar* surface 1, $\frac{5}{8}$, $\frac{6}{8}$, inch; from the *dorsal* surface $\frac{2}{8}$, $\frac{2}{8}$, $\frac{4}{8}$ inch.

II. The Carpus in Fin-whales.

1. *In Balænoptera musculus.*

I take this species first and chiefly as I have seen most of it. The carpal cartilages and bones are described in detail in my paper "On some points in the anatomy of a great fin-whale" (loc. cit., 1871, p. 124), and figures, 1 and 2, are there given of the outlines of the carpal cartilages and bones on the palmar and dorsal aspects, with the finger muscles. For exact comparison with Mysticetus, I give here, in figure 6, a view of a section of the carpus, &c., of a 45-feet-long female B. musculus, obtained in 1889, being my fifth of that species. All the parts here, cartilages, articulations, and ossifications, are well seen on the surfaces and in the sections of both wrists, affording an excellent opportunity for the study of the parts. The surface of these large cartilages and bones exposed by horizontal section in the fresh condition presents quite a beautiful appearance to the anatomical eye.

Cartilages.—The palmar and dorsal surfaces present the same general appearance of strongly marked furrows as in Mysticetus, the mass about half the size of that in the latter; and the section displays the same fine lines of soft fibrous suture between the cartilages, isolating and uniting them. The lines of suture are finer here, but are distinctly seen on section with the saw and on slicing with a large thin knife through and through. There are no synovial cavities anywhere between the carpal or metacarpal cartilages or at the wrist joint.

As in Mysticetus, the furrows on the palmar and dorsal surfaces correspond exactly, and also to the lines of fibrous suture seen on section. The correspondence was apparent to the eye on viewing the surfaces variously, and was proved by the table of measurements I had made. There was also

symmetry between the right and left carpus. As in Mysticetus, therefore, the articulations of these great cartilages pass through and through at right angles to the surface; so that, closely united as they are by fibrous tissue, extremely little movement can take place between them, indeed none giving them a function by movement on each other.

In the *first row* are seen *four* cartilages, the radiale, intermedium, and ulnare, well ossified, leaving a comparatively narrow surrounding of cartilage, and the entirely cartilaginous pisiform. In the *second row* occur *two*. They may be regarded as carpalia III and IV (the magnum and unciform), and may be described as the radial and ulnar disto-carpals. They are not so large as those in the first row but are as fully ossified in proportion to their size. The measurements of these cartilages and their ossifications are given in the first division of Table II.

Other measurements of the 45-feet-long B. musculus.—Breadth of carpus, to pisiform $8\frac{3}{4}$ inches, with pisiform 12. Length, average, $3\frac{1}{2}$ inches. Thickness of carpus, at the intermedium $2\frac{1}{8}$ inches; at the radiale 2; at the ulnare $1\frac{1}{2}$; at carpale III, 3 inches; at carpale IV, $1\frac{3}{4}$ inches. Bony epiphysis of radius, $4 \times \frac{7}{8}$ inches; that of ulna, $2 \times \frac{5}{8}$ inches. *In the 65-66-feet-long B. musculus*, thickness (from palmar to dorsal surface) of carpal bones, radiale $3\frac{1}{4}$ inches; intermedium $2\frac{3}{4}$; ulnare $1\frac{3}{4}$; carpale III, 3 inches; carpale IV, 2 inches.

The *articulations* of each carpal cartilage need not be repeated here (given loc. cit., 1871, p 124); they are seen in figure 6, but the following points may be noted. The intermedium does not touch the ulna, being separated from it by the angle of the ulnare that reaches the radius and is in contact with it for about $\frac{1}{4}$ inch in both wrists. Thus, there is no ascent of the intermedium between the radius and ulna. The pisiform continues the series of the first row by articulating with the ulnare as well as with the side of the ulna, and, by a narrow facet, it helps to support digit V. The two disto-carpals are placed together, forming a base to the two great middle digits, III and IV. The radial disto-carpal (carpale III) supports also nearly half of the base of lateral digit, II. The ulnar disto-carpal (carpale IV) supports also about a third of the base of lateral digit V. Thus, the lateral digits rest mainly on the bones of the first row, respectively on the radiale and on the ulnare and pisiform.

The *ossifications* (carpal "bones"), as seen in the median

TABLE II.—*Giving the measurements of—(1) In the 45-feet-long B. musculus, in the moist condition, the carpal cartilages and ossifications seen in horizontal section (fig. 4), and the extent of bone seen on the palmar and dorsal surfaces uncovered by cartilage. Left carpus only, but symmetrical. (2) In the* $60\frac{1}{2}$*-feet-long B. musculus, in the dried condition, the bones in horizontal section, and the extent of bone seen on the palmar and dorsal surfaces uncovered by cartilage. Left carpus only. Ossification much more advanced in this individual. (3) In the 65-66-feet-long B. musculus, the carpal bones fully exposed by maceration (fig. 7). The measurements give the entire breadth and length of the bones on the palmar and dorsal surfaces. Measurements in third last column omitted as uncertain, the articulating surfaces being at some parts convex at some parts concave; on the whole, the bones of this aged carpus are as large on the surfaces as at the middle. Left carpus only. The measurements, given in inches, are transverse and longitudinal, the transverse always placed first.*

	In the 45-feet-long B. musculus.				The $60\frac{1}{2}$-feet-long B. musculus.			The 65-66-feet-long B. musculus.		
	Cartilages.	Bones.	Bones seen on surfaces.		Bones.	Bones seen on surfaces.		Bones.	Bones entire measurements.	
		Section.	Palmar.	Dorsal.	Section.	Palmar.	Dorsal.	Between.	Palmar.	Dorsal.
Radiale,	$2\frac{7}{8} \times 2\frac{1}{4}$	$2\frac{7}{8} \times 2$	$1\frac{1}{2} \times 1\frac{1}{8}$	$1\frac{1}{8} \times \frac{3}{4}$	$3\frac{5}{8} \times 3$	$3\frac{1}{8} \times 2$	$3\frac{1}{8} \times 2\frac{1}{4}$	Not larger than at the surfaces.	$4\frac{1}{2} \times 2\frac{1}{2}$	$4\frac{1}{2} \times 2\frac{1}{2}$
Intermedium,	$2\frac{1}{2} \times 2\frac{5}{8}$	$1\frac{3}{4} \times 2$	$\frac{7}{8} \times 1$	$\frac{7}{8} \times 1$	$3\frac{1}{2} \times 3\frac{1}{4}$	$2\frac{5}{8} \times 2\frac{1}{2}$	$1 \times 1\frac{1}{4}$		$3\frac{1}{2} \times 4$	$3\frac{3}{4} \times 3$
Ulnare,	$3\frac{1}{4} \times 3$	$2\frac{3}{4} \times 2\frac{3}{8}$	$2\frac{1}{4} \times 2$	$2\frac{1}{4} \times 2$	$4 \times 3\frac{5}{8}$	$3\frac{1}{2} \times 3\frac{3}{4}$	$3\frac{5}{8} \times 3\frac{1}{8}$		$4\frac{1}{2} \times 3\frac{1}{2}$	$4\frac{1}{2} \times 3\frac{1}{4}$
Pisiform,	$3\frac{1}{4} \times 3\frac{1}{2}$	...	...	...	$1\frac{1}{2} \times 1\frac{3}{4}$	$1 \times 1\frac{1}{4}$	$\frac{7}{8} \times 1\frac{1}{8}$	?	?	?
Carpale II,	...	...	...	...	Cart.	Cart.	Cart.	2×1	...	...
Carpale III,	$2\frac{3}{4} \times 1\frac{3}{4}$	$2 \times 1\frac{1}{4}$	0	$\frac{3}{4} \times \frac{1}{2}$	$3 \times 2\frac{1}{8}$	$\frac{1}{4} \times \frac{1}{4}$	$1\frac{7}{8} \times 1\frac{7}{8}$	Not larger than at surfaces.	$3\frac{1}{2} \times 2\frac{1}{8}$	$3\frac{3}{4} \times 2\frac{1}{4}$
Carpale IV,	$2\frac{1}{8} \times 2$	$2\frac{1}{8} \times 1\frac{1}{8}$	$1\frac{5}{8} \times 1\frac{1}{4}$	$1\frac{5}{8} \times 1$	$3\frac{1}{4} \times 2\frac{5}{8}$	$2\frac{3}{4} \times 2\frac{5}{8}$	$2\frac{1}{2} \times 2\frac{1}{8}$		$3\frac{3}{4} \times 2\frac{5}{8}$	$4 \times 2\frac{3}{4}$

TABLE III.—*Showing, in the other three great Fin-whales, now in the dried condition:*—(1 *and* 2) *In the two B. musculus, the extent of bone seen on the palmar and dorsal surfaces, not covered by cartilage;* and (3) *In the B. borealis, the entire extent of the bones on these surfaces, including the parts covered by cartilage, the whole extent being visible through the cartilage. Both right and left sides are given to show the symmetry or the near approach to it. Pisiform not ossified in any of the three. Carpale II present in the 50-feet-long B. musculus as a cartilage,* $1\frac{1}{4} \times 1\frac{1}{4}$ *inches. The measurements, given in inches, are the transverse and longitudinal, the transverse always placed first.*

	B. musculus 64-feet-long.				B. musculus 50-feet-long.				B. borealis 36-feet-long.			
	Palmar seen.		Dorsal seen.		Palmar seen.		Dorsal seen.		Palmar entire.		Dorsal entire.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
Radiale, . . .	$3\frac{3}{8} \times 2\frac{1}{4}$	$3 \times 2\frac{1}{2}$	$3\frac{1}{4} \times 2$	$3 \times 2\frac{1}{8}$	$2\frac{1}{4} \times 1\frac{1}{2}$	$2\frac{1}{4} \times 1\frac{5}{8}$	$2\frac{1}{4} \times 1\frac{1}{4}$	$1\frac{1}{4} \times 1$	$1\frac{1}{4} \times 1\frac{3}{8}$	$1\frac{3}{8} \times 1\frac{1}{4}$	$1\frac{1}{4} \times 1\frac{3}{8}$	$1\frac{3}{8} \times 1\frac{1}{4}$
Intermedium, . .	$3\frac{1}{8} \times 3$	$3\frac{1}{4} \times 2\frac{7}{8}$	$3 \times 2\frac{5}{8}$	$3\frac{1}{4} \times 2\frac{1}{8}$	$1\frac{5}{8} \times 1\frac{3}{4}$	$1\frac{3}{8} \times 1\frac{3}{4}$	$2 \times 1\frac{5}{8}$	$1\frac{3}{4} \times 1\frac{3}{8}$	$1\frac{3}{8} \times 1\frac{3}{8}$	$1\frac{1}{4} \times 1\frac{3}{8}$	$1\frac{1}{2} \times 1\frac{3}{8}$	$1\frac{1}{2} \times 1\frac{3}{8}$
Ulnare, . . .	$4 \times 3\frac{1}{8}$	$3\frac{3}{4} \times 3$	$4 \times 4\frac{1}{2}$	$3\frac{3}{4} \times 2\frac{3}{4}$	$2\frac{3}{8} \times 2\frac{3}{8}$	$2\frac{3}{8} \times 2\frac{1}{4}$	$2\frac{1}{2} \times 2\frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{8}$	$2\frac{1}{8} \times 1\frac{3}{4}$	$2 \times 1\frac{5}{8}$	$2 \times 1\frac{3}{4}$	$2 \times 1\frac{3}{4}$
Pisiform—	...	...	...	...	...	...	...	...	...	...	...	...
Carpale II, . .	...	...	...	...	Cart.	Cart.	Cart.	Cart.	...	...	...	...
Carpale III, . .	$2\frac{3}{8} \times 1\frac{1}{2}$	$2\frac{3}{8} \times 1\frac{1}{2}$	$3\frac{1}{8} \times 1\frac{3}{4}$	$2\frac{1}{2} \times 1\frac{5}{8}$	$\frac{1}{8} \times \frac{1}{8}$	$\frac{1}{4} \times \frac{1}{4}$	$1 \times \frac{3}{4}$	$1 \times \frac{3}{4}$	$1\frac{3}{4} \times 1\frac{1}{8}$	$1\frac{3}{4} \times 1$	$1\frac{3}{4} \times 1\frac{1}{4}$	$1\frac{1}{4} \times 1\frac{1}{8}$
Carpale IV, . .	$2 \times 1\frac{1}{4}$	$2 \times 1\frac{3}{8}$	$\frac{3}{4} \times \frac{5}{8}$	$1\frac{1}{4} \times 1$	$1\frac{1}{2} \times 1\frac{1}{4}$	$1\frac{5}{8} \times 1\frac{3}{8}$	1×1	$1\frac{1}{2} \times 1\frac{1}{8}$	1×1	1×1	$1\frac{1}{8} \times 1\frac{1}{8}$	$1\frac{1}{8} \times 1$

horizontal sections, are symmetrical, so much so that, as when the palmar surface of one carpus is turned over and laid alongside the dorsal half of the other carpus, it is difficult to tell the one from the other by the carpal ossifications alone. In regard to the comparison of the area of each bone as seen in median horizontal section with the area seen on the surfaces, not overlapped by cartilage, the extent on the surface is less, on all the bones, by from half an inch to an inch. This is seen in the first division of Table II. When a section cannot be made, the full dimensions of the concealed part may be ascertained, in the moist condition, by puncture with needles.

Relative amount of ossification on the Palmar and Dorsal surfaces.—The effect of ossification will be to stiffen the carpus. Were it greater on the dorsal than on the palmar surface, the effect would be to give more resistance behind, as against the stroke of the palmar surface of the fin against the water, assisting in this respect the predominance of the flexor over the extensor finger-muscles. The greater progress of ossification towards the dorsal than to the palmar surface noted in the younger Mysticetus, led me to look to this point in the large Finners, and to the conclusion that there is no general rule as to predominance of ossification towards either surface.

The following is the evidence:—

The measurements given in Tables II. and III. show that there is no definite law as to predominance on either surface among the bones of the first row (pro-carpals), but in the case of the radial disto-carpal (carpale III), the smallest of the ossifications as seen on section, it has made its appearance only on the dorsum in the youngest B. musculus, and the dorsal measurements of this bone are decidedly greater than the palmar in the other four B. musculus. The same rule, however, does not apply to the ulnar disto-carpal (carpale IV) in these B. musculus, in most of them rather the reverse; nor in B. borealis does it apply to the radial disto-carpal (c. III) of the left carpus, in which this disto-carpal is, in both wrists, not smaller than the ulnar disto-carpal (c. IV).

On the whole, therefore, it would seem that, among these five B. musculus, there is no general rule of predominance of ossification towards the dorsal rather than the palmar surface, except in the case of the radial disto-carpal (c. III). Running the eye along Tables II. and III. it is seen, in regard to the other carpal bones, that the predominance is sometimes on the dorsal sometimes on the palmar surface, and that not infrequently there is no difference. The difference of $\frac{1}{8}$ inch, here and there on such large structures, need not be founded on.

The most useful of the comparisons are those given in the first and third divisions of Table II., those of the youngest and of the aged B. musculus; more especially the latter, in which the bones may be considered as having reached their full size, and in which any little difference, on the whole, is rather in favour of predominance at the palmar surface.

Variation in the Carpus of B. musculus.—The individuals of this species (the Razor-back whale, *Balænoptera musculus*) here referred to are:—

1. 65-66-feet-long, male, at Wick, June, 1869.
2. 64-feet-long, male, at Peterhead, June, 1871.
3. 60½-feet-long, male, at Stornoway, Nov., 1871.
4. 50-feet-long, male, at Nairn, Dec., 1884.
5. 45-feet-long, female, at Bervie and Aberdeen, Oct., 1889.[1]

I have noted the following variations among the five B. musculus.

First Variety. Incomplete separation of certain cartilages.—In two places, the separation, well seen on section, did not exist on the surface.

(a) The radiale and intermedium represented by a common cartilage. This was complete on both surfaces in the 50-feet-long individual. The same in the 45-feet-long individual on the palmar surface of the left carpus, and the separation but faintly marked on the palmar surface of the right; but on section, the separation is as well marked between these two cartilages as anywhere in the carpus. (b) The carpal epiphyses of metacarpals III and IV represented by a common cartilage. This occurred in both wrists of both the individuals just mentioned, no furrow or mark present on either surface. But when sections were made in the latter individual, the two cartilages were seen to be distinctly marked off from each other by lines of fibrous suture, as shown in fig. 6.

[1] The first four of these have already been noticed in papers on various parts of their anatomy in this *Journal* (Nov. 1871, Nov. 1872, April 1893). The fifth has not hitherto been noticed, except in the account I wrote of its external characters in the *Scotsman* of October 28th, 1889. It had become entangled in a trawl net off Bervie, Kincardineshire, and was said to have been killed after a struggle. It was then towed round to Aberdeen harbour, where I noted its external characters. It had all the characters of B. musculus well marked. I was unable to do more than secure the parts described in this paper, being unwell at the time and on the eve of leaving Aberdeen University. I obtained the bones of the Nairn B. musculus for Aberdeen University and had the skeleton prepared. The pectoral limbs of the Peterhead and Stornoway B. musculus are in the anatomical museum of Aberdeen University, that of the Wick B. musculus is in the anatomical museum of Edinburgh University, presented by me to these museums.

Second Variety.—The *pisiform* appears to vary considerably in B. musculus, in regard to articulation, form, and ossification.

In the 45-feet-long individual, the separation between it and the epiphysis of the ulna is, in its proximal half, indicated only by a soft white line, in its distal half by distinct fibrous suture. That incomplete separation of the proximal part is noted below as met with in other Finners, as B. rostrata and Megaptera. In this B. musculus, as seen in fig. 6, it articulates in part with digit V, but in the figure of the 64-feet-long individual (loc. cit., 1871, figs. 1 and 2) it is seen not to reach nearly so far down. Its variation in *form* appears to be considerable, but that is probably a matter of age, in part at least. In the figures just referred to, the pisiform is square-shaped, rising to a peak where I found the tendon of the flexor carpi ulnaris muscle to be attached. In the 45-feet-long individual (fig. 6) it begins by a narrow pedicle, for about ⅓ of its breadth, and then expands into an ovoid plate. On comparing the two figures, it is seen that the difference in form is owing to the ulnare in the less grown individual not reaching out as far as the free edge of the ulnar epiphysis, as it does in the older one, thus requiring the elongated pedicle. The pisiform shows *ossification* in only one of the five, the 60½-feet-long one; the ossification 1½ by 1¾ inches. No note has been kept of the condition of the pisiform in the 65-66-feet-long individual, but it is not ossified in the 64-feet-long one.

Third Variety.—*Occurrence of a third disto-carpal;* at the radial side, placed in between the radiale and metacarpal II; corresponding to the trapezoid, carpale II of the typical carpus.

As this bone, or cartilage, was present in three of the five (Nos. 1, 3, and 4) it is a question whether it is to be regarded as normal rather than as a variety. It contained an ossification in No. 1, and was entirely cartilaginous in Nos. 3 and 4.

The bone is shown in fig. 7, which represents the carpal bones, &c., of the 65-66-feet-long B. musculus, drawn from the skeleton, the cartilages now gone, but the ossicle, 2 inches by 1 inch, is articulated in its natural position. As the two usual disto-carpals have undergone partial synostosis, this individual may be inferred to have been aged. Only the left paddle was obtained.

In the 60½-feet-long individual this "trapezoid" cartilage was well marked off by furrows on both surfaces. A section was made only lately, displaying a triangular area of dried cartilage, but no ossification. Only the left paddle was obtained.

In the 50-feet-long individual, this triangular "trapezoid" cartilage, about 1½ inch each way, was, on both palmar and dorsal surfaces, distinctly marked off by fibrous suture on the right carpus; less decidedly so, but visible, on the left. The specimen is now dried and has lost all appearance of distinctness of this cartilage. On section,

made lately, no ossification was seen. Here we see this cartilage marked off on the surfaces, while those of the intermedium and ulnare, and the proximal epiphyses of digits III and IV, were not.

In the 64-feet-long individual, there is no record as to this third disto-carpal bone or cartilage. It was my first B. musculus. There is no appearance of it now in the dried paddles. In the 45-feet-long individual, figured (fig. 6) and described above, still preserved moist, there is no appearance of a "trapezoid" disto-carpal, either on the surfaces or in the sections of either carpus.

Fourth Variety. Synostosis of the two usual disto-carpals.—This condition occurs in the 65-66-feet-long individual, as shown in fig. 7. The two bones (carpalia III and IV) supporting the two great digits have become largely united, on both surfaces but not deeply.

A well marked groove, about $\frac{1}{8}$ inch in breadth, crosses the bone longitudinally at the middle. A thick plate of bone unites the two bones on the palmar and dorsal surfaces and distally, leaving a large cavity, measuring 2 inches between the plates and $1\frac{1}{2}$ longitudinally, open above towards the intermedium. These particulars show that the bone has begun by two ossifications which have been thus united in this aged individual. This would be explained, so far, on the supposition that the two bones had originally a common cartilage. The carpal bones, comparatively smooth and flat on the palmar surface, are, like the neighbouring parts of the radius and ulna, much roughened on the dorsal surface by longitudinal vascular grooves and foramina; contrasting with the comparative smoothness of the metacarpal bones.

Fifth Variety. Articulation of digit IV in part with the radial disto-carpal.—In the figures given in 1871 of the 64-feet-long B. musculus, this disto-carpal (corresponding to typical carpale III, the os magnum), besides supporting the whole of digit III and about half of digit II, articulates with digit IV by an angular facet. But in the 45-feet-long B. musculus, as shown in figure 6, the radial disto-carpal does not articulate with digit IV.

A little fibrous tissue filled the small space left at the meeting of the four fibrous sutures. I am not likely to have been in error as to this point in the 1871 B. musculus as I commented on it then as in that respect resembling the relation of the os magnum to the metacarpus in man.

2. *In Balænoptera borealis* (the Black Whale, Rudolphi's Rorqual).

The observation of the carpus was made on a 36-feet-long male.[1]

In the carpus there were no surface grooves indicating the presence of a "trapezoid" disto-carpal (carpale II). A section was not made. The carpal cartilages, and well-ossified bones, correspond to those figured (fig. 6) in B. musculus with the following differences. (1) Separation of the cartilages of the two disto-carpals, though discernible, was obscurely marked, especially on the palmar surface. (2) The carpal epiphyses of all the metacarpals were entirely separate. (3) The radial disto-carpal articulated with digit IV as well as with digits II and III. (4) The epiphysis of the ulna sent out a large triangular projection between the pisiform and the ulnare, which might be mistaken for a carpal cartilage. The pisiform was distinct from this projection, but its other articulations and its form could not be accurately noted.

3. In *Balænoptera rostrata* (The Lesser Fin-whale, the Pike-whale of John Hunter).

The observations on the carpus were made on

1. A 14½-feet-long female, right carpus dissected.[2]
2. A 16-feet-long female, both wrists dissected.

From the figure given (fig. 8) of the carpus, &c., of this species, it will be seen that the number, form, and general arrangement of the *carpal cartilages* is the same as that described and figured above (fig. 6) in B. musculus, except that the intermedium articulates also with the ulna, and that the pisiform has a very different shape.

The *intermedium* articulates with the ulna for ¼ inch, and is, accordingly, more elongated transversely than in B. musculus, being equal in breadth to the ulnare; and at the same time sends up a short obtusely angular projection between the radius and ulna. The *pisiform* has

[1] Killed at Widewall Bay, Orkney, December 1884. I obtained the bones and had the skeleton prepared for the Anatomical Museum of Aberdeen University. References occur to the skeleton in my comparison of the osteology of Megaptera with that of B. musculus, *loc. cit.*, 1887–8–9, but my hope to be able to give a comparison of the osteological characters of B. borealis with those of B. musculus is not yet fulfilled.

[2] This B. rostrata was stranded alive at Aberdeen in July 1870. I made full notes of the characters and of various parts of the anatomy. The skeleton is in the Anatomical Museum of Aberdeen University. The 16-feet-long B. rostrata was beached at Bervie, Kincardineshire in April 1877. I obtained the paddles only.

the pedicle with the same articulations as in B. musculus, but undergoes very little expansion in its continuation upwards. It wants, as compared with B. musculus, the distal part of the expansion towards the free margin of the paddle.

Ossifications.—As these two B. rostrata were only about half-grown, the ossicles are, relatively to their cartilages, smaller in the figure (fig. 8) of B. rostrata than in that of the two-thirds-grown B. musculus (fig. 6).

In B. rostrata the intermedium is broader than the ulnare, following the increased breadth of its cartilage. The radial disto-carpal (carpale III) is the smallest in both. The ossicles are seen to lie in the direction of the long axis of their cartilages, and to send out angles towards the angles or ends of their cartilages. The intermedium and ulnare are placed rather towards the side of their cartilages nearest the centre of the wrist; the radiale rather towards the side next the free border; the two disto-carpals at the middle of their cartilages, opposite the digits they have to support.

The radial disto-carpal (c. III), the smallest of the ossifications, did not show itself on either surface, and might have been overlooked; the radiale not much. It was not evident that the extent to which the other ossicles had reached the surface was greater on one surface than on the other. They are convex to both surfaces, and more or less overlapped by cartilage which has to be sliced away to expose the full size of the ossicles. The measurements made show, what is pretty evident to the eye, that, in all of these three wrists examined in B. rostrata, the cartilages and bones are of precisely the same form and size, except that in the $14\frac{1}{2}$-feet-long one the radial disto-carpal (c. III) was larger than in the 16-feet-long one; $\frac{7}{12} \times \frac{5}{12}$ against $\frac{5}{12} \times \frac{3}{12}$ inch.

Incomplete separation of some of the Cartilages.—The following instances may be noted in which the separation of the cartilages was either only partial, or seen only on section, or faintly marked, or apparently not present. It has to be kept in mind that these B. rostrata were only half-grown, and that the parts are not on such a great scale as in Mysticetus and the Great Finners. The parts, however, were carefully observed, and when necessary, with the help of a lens.

(a) The separation of the *pisiform* from the cartilaginous epiphysis of the ulna was, on the proximal half of that relation, obscure, indicated only by a fine milky line. On the distal half there was a distinct fibrous suture. (b) The carpal epiphyses of all the metacarpals, except that of digit V, were continuous with each other on the surface, but on section, fine lines of separation came into view, formed of soft substance. (c) The two disto-carpal ossicles were inclosed in a common cartilage on the palmar surface, with only a slight indication of separa-

tion on the dorsal surface, easily overlooked. But on slicing, a faint milky line, not sharply defined and easily overlooked, was seen dividing the cartilage along the middle, through and through. The best marked fibrous sutures were those at the distal ends of the first carpal row, more so, apparently, than at the wrist joint.

In the carpus of these B. rostrata we see the stages of development of the joints; first, a faint milky line; then soft substance; and finally, distinctly formed fibrous tissue. A more complete stage would be the development of a diarthrodial joint, instead of fibrous tissue, as noted to occur in Megaptera at the radial disto-carpal, the supporting cartilage of the greatest digit. In examining the fibrous sutures in a small carpus, it is advantageous to use some temporary stain, as magenta, applied with a brush and then wiped off. The fibrous sutures become more distinct, but the milky lines do not take in the stain.

TABLE IV.—*Giving, in inches, the transverse and longitudinal measurements of the Carpal Cartilages and Ossifications in the* 16-*feet-long Balænoptera rostrata.*

In the 16-feet-long B. rostrata.	Cartilages.		Bones.		
	Trans.	Long.	Trans.	Long.	Thickness.
Radiale, ...	$1\frac{3}{12}$	$\frac{8}{12}$	$\frac{9}{12}$	$\frac{6}{12}$	$\frac{7}{12}$
Intermedium, . . .	$1\frac{3}{12}$	$\frac{9}{12}$	$\frac{10}{12}$	$\frac{7}{12}$	$\frac{9}{12}$
Ulnare, ...	$1\frac{3}{12}$	$\frac{11}{12}$	$\frac{9}{12}$	$\frac{7}{12}$	$\frac{7}{12}$
Pisiform, ...	$\frac{9}{12}$	$2\frac{1}{2}$	...	...	...
Carpale III, ...	1	$\frac{7}{12}$	$\frac{5}{12}$	$\frac{3}{12}$	$\frac{5}{12}$
Carpale IV, ...	$1\frac{1}{12}$	$\frac{9}{12}$	$\frac{8}{12}$	$\frac{6}{12}$	$\frac{7}{12}$
Entire carpus, to Pisiform, .	4	$1\frac{1}{2}$	...	...	...
,, with Pisiform,	$5-5\frac{1}{4}$	...	...	...	...

In both of these B. rostrata the bony epiphyses of the humerus and at the proximal end of the radius and ulna are still not united to the shafts. That at the distal end of the humerus is one continuous plate. The elbow joint was synovial throughout; the same for $\frac{1}{2}$ inch between the radius and ulna, continued from the elbow. The distal epiphyses of the radius and ulna are not ossified. They are in contact for about $\frac{1}{4}$ inch. The wrist joint was fibrous only, like the carpal joints.

4. *In Megaptera longimana.*

The carpal cartilages and ossifications are described and figured in my account of a 40-feet-long male of this species of

fin-whale (loc. cit., 1888, p. 252, figs. 6 and 9), and are here alluded to for comparison only. The remarkable difference from the other finners is the great extent transversely (10 inches) of the ulnare, occupying the position of an intermedium also. The intermedium and radiale (about 4 inches each) were opposite the radial $\frac{2}{3}$ of the radius. If it be suggested that this great ulnare represents the intermedium also, then there would be 4 pro-carpal cartilages besides the pisiform. The pisiform has the square-shaped expansion figured in the 64-feet-long B. musculus (loc. cit., 1871, figs. 1 and 2), rather than the form in the 45-feet-long B. musculus seen in figure 6.

For the second row, Megaptera has the two usual disto-carpals (c. III and IV) of Finners, supporting the two long digits. The radial disto-carpal (c. III) is rather the larger of the two; broad enough to articulate with digits II and IV besides supporting the great digit, III; and its articulations above and below are synovial, the proximal wholly, the distal partly.

Another remarkable contrast, was the little advancement *ossification* had made in the Megaptera. Ossicles were present in the ulnare, to its ulnar side, and in the radiale, but they were small for a $\frac{4}{5}$ grown, if not more fully grown, individual. The ulnare-ossicle was only $1\frac{1}{2} \times 1\frac{1}{2}$ inch in a ten-inch-broad cartilage. The epiphysis of the radius had a rather small-sized ossification; that of the ulna a very small one. Contrast with these the advanced state of ossification of the carpus and the epiphyses above it, shown in fig. 6, of the $\frac{2}{3}$ grown B. musculus, and of the carpus, shown in fig. 8, of the only half-grown B. rostrata.

III. Comparison of the Carpus in Mysticetus and in Fin-whales.

I propose here to remark on the differences seen on comparing the carpus of Mysticetus with those of the Balænopteræ, the facts regarding each species having been given separately in the two previous divisions of the paper.

(a) *In the first carpal row* (pro-carpals) the same bones, or their cartilages, occur, but with differences. The *radiale* in Mysticetus is the smallest in the row, and not ossified in the adult. It supports the rudimentary pollex, while in the Finners it

supports the well-developed outer digit, usually regarded as digit II in these four-fingered whales, assuming the pollex to be wanting. Even were the observation of Kükenthal, of the presence of a rudimentary digit in an embryo, in the position of what would be the middle of a five-fingered hand, to be confirmed, it would be inconvenient now to alter the nomenclature. This difference in the digital support afforded by the radiale may account for its less development in Mysticetus.

The *intermedium* in Mysticetus ascends between the epiphyses of the radius and ulna, and also, to a less extent, in B. rostrata, but not in B. musculus, the ulnare cutting it off from contact with the ulna. The *ulnare* is, of the first row, much the largest cartilage in Mysticetus and is the largest in all these Finners, extraordinarily so in Megaptera. It has rather the largest ossification in Mysticetus, decidedly so in the Great Finners, but as yet not quite the largest in these half-grown B. rostrata.

The *pisiform* in Mysticetus does not articulate with the ulnare, widely cut off from it by digit V ascending to articulate with the ulna. In all the Finners the pisiform articulates with the ulnare, continuing the series of the first carpal row, and has a much narrower articulation with digit V than in Mysticetus. The setting of digit V in Mysticetus upon the ulna, in between the pisiform and the ulnare, and the greater breadth of the articulation of the pisiform with digit V, may be regarded as in adaptation to the greater breadth of the five-fingered hand, together with the exceptionally great breadth of the base of digit V and the divergent direction of that digit. Perhaps, it may be said that the longitudinal extension of the ulnare, as it has to do duty for an absent disto-carpal in supporting digit IV as well as digit V, may be a reason for its not undergoing sufficient extension transversely, thus allowing digit V to find its way to the ulna for firm support.

The *form of the pisiform* is very different, having much less expansion towards the end in Mysticetus, but much more projection transversely beyond the line of the ulna than in the Finners. This projection in the 48-feet-long Mysticetus is for fully 5 inches, while in B. musculus it is only 2 inches in the 45-feet-long one and but 3 inches in the 64-feet-long one. The pisiform is also considerably thicker in Mysticetus than in B. muscu-

lus. This greater projection and thickness of the pisiform in Mysticetus is in accordance with the greater breadth of the limb, and the adaptation is seen in the dissection of the soft parts, to which it serves as a stretcher and support. In Mysticetus it supports distally the great ulnar fibrous curtain, ½ inch to 1 inch in thickness, 5 to 6 inches in breadth where it joins the pisiform, the expanding tendon of the flexor carpi ulnaris muscle contained within it (loc. cit., 1878, p. 217). This curtain is not present in the much narrower limb of B. musculus, in which the tendon of that muscle keeps distinct down to its insertion to the peak on the proximal border of the pisiform (loc. cit., 1871, p. 111 and fig. 1 there).

(b) *In the second carpal row* the difference is great. In the *Finners*, the rule is the occurrence of the two disto-carpals, carpalia III and IV, in the nomenclature of Gegenbaur, corresponding to the usual mammalian and human magnum and unciform. These project somewhat and support the two middle digits (III and IV) which are the two long digits. Digit III is the longer and thicker of the two, but its supporting disto-carpal (carpale III) is not always the larger of the two. As seen in Tables II. and III., carpale IV is rather the largest of the two disto-carpals in B. musculus; decidedly so in the half-grown B. rostrata; but not so in B. borealis, nor in Megaptera. In the latter, carpale III, supporting much the greatest digit, is considerably larger than carpale IV, and its joints above and below are synovial, the distal one partially, the proximal one in its whole breadth. Any difference in size between carpalia III and IV is not accounted for by the relative extent to which they support also digits II and V (see fig. 6), though it may be so in the case of B. rostrata (fig. 8).

But the adaptation to function, so far, in these two disto-carpals in all the Finners is evident, as specially giving support to the two great digits. If one may risk suggesting a functional explanation of the peculiarities of the carpals in Megaptera (loc. cit., 1888, figs. 6 and 9), it may be that the enormous breadth of the radial digit, II, has appropriated for the support of that digit the intermedium as well as the radiale, while the transversely enormous ulnare gives firm support to the two disto-carpals.

In *Mysticetus* the second carpal row is represented by only

one great disto-carpal, transversely elongated, supporting digits II and III; the very large ulnare coming down and supporting digits IV and V, occupying the place of the ulnar disto-carpal in the Finners. If an identity is to be assigned to this great disto-carpal in Mysticetus, it may be regarded as carpale III, extended radially, the ulnare taking the place of the absent carpale IV. The objections to regarding this great disto-carpal as carpalia III and IV united are, the single ossification occurring in it opposite both digits II and III, and that the cartilage shows no trace of subdivision anywhere. It is not legitimate to reckon, and nothing is gained by reckoning, any one bone as representing two of the typical carpus unless it can be shown that there were originally two cartilages or two ossifications. If that rule is disregarded and the great solitary disto-carpal held to represent two disto-carpals, then the ulnare would have to be held as representing a disto-carpal as well as a pro-carpal. As a matter of adaptation, we see that the two longest digits, III and IV, rest each on one of the two largest bones of the carpus; the longest, digit III, on the great solitary disto-carpal, the other on the prolonged ulnare.

Looking at the proportions of the entire carpus, excluding the pisiform, the breadth and length are, in the 48-feet-long Mysticetus, respectively, 20½ inches and 8 inches; in the 45-feet-long B. musculus 8¾ and 4 inches. The carpus, therefore, is considerably broader in proportion to its length in Mysticetus than in B. musculus. That, together with its great thickness, means less flexibility of the carpus in Mysticetus, and a more solid basis of support is given to the four great digits by the transverse elongation of a solitary disto-carpal, and by the longitudinal enlargement of the ulnare with suppression of a second-row bone between it and the metacarpals. These conditions may be regarded as adaptations to greater solidity of the carpus in Mysticetus than in the great Finner.

Variations of the Cartilages and Ossifications.

In the course of the preceding account of the cartilages and ossifications, instances occur in which cartilages usually separate were not completely so, of completely isolated carpal cartilages

in the adult without ossification, and of ossification occurring without the inclosing cartilage being isolated. These may be summarised thus, and in estimating them age has to be kept in view.

In the Fin-whales. (a) Instances of cartilages which never ossify in whale-bone whales, usually distinct but found only partially separate. These are the *carpal epiphyses of the metacarpal bones.* (1) In the two half-grown B. rostrata, the only one completely isolated was that of digit V, the others were continuous on the surfaces but separate deeply. (2) In the 45-feet-long and in the 50-feet-long B. musculus, those of digits III and IV were continuous on both surfaces in both wrists, but in the interior were separated by lines of fibrous suture.

(b) The *pisiform*, which may ossify more or less with age, is sometimes only obscurely separated from the cartilaginous epiphysis of the ulna at its proximal half; merely by a milky line, instead of by the usual fibrous suture. This was seen (1) In the two half-grown B. rostrata: (2) In the 45-feet-long B. musculus: (3) In the 60½-feet-long B. musculus, in which the pisiform was partly ossified. In the other three B. musculus and in B. borealis the separation was by fibrous suture throughout. (4) In the 40-feet-long Megaptera, separation on the proximal ⅔ was indicated by surface grooves, but did not exist in the interior. The late and very partial ossification, or the non-ossification, of the pisiform in these cetaceans may be regarded as a functional adaptation if lateral flexibility is of advantage at this part.

(c) The cartilages of *the two disto-carpals:* In the two half-grown B. rostrata, not distinctly separate on the surfaces, but in the interior the separation indicated by a milky line. (d) The well-ossified cartilages of the *radiale and intermedium* were, (1) in the 50-feet-long B. musculus, continuous on both surfaces; (2) in the 45-feet-long one, continuous on the palmar surface in the left carpus; but in both individuals well-separated in the interior. (e) The occurrence of an *additional disto-carpal* (carpale II, trapezoid bone) in three of the five B. musculus; ossified in the aged one, cartilaginous in the 60½-feet-long one, and in the 50-feet-long one; not present in the 45-feet-long one. (f) *Synostosis* of the two usual disto-carpals in the aged (65-66-feet-long) B. musculus.

In Mysticetus. In the 48-feet-long female: (1) The *radiale* not ossified in either carpus, and not separated from the pollex at its radial fifth: (2) The *pollex* represented by one undivided cartilage: (3) The solitary *disto-carpal*, equally marked off in both wrists, ossified in the right wrist only.

In the 35-feet-long male: (1) The *radiale*, though ossified, not separate from proximal epiphysis of pollex: (2) *Metacarpal of pollex* well ossified: (3) *Carpal epiphysis of digit II* partially continuous with the disto-carpal cartilage: (4) The *ulnare* not ossified, though cartilage well marked off, and this the most advanced ossification in the adult female.

These variations raise interesting questions as to the meaning of the presence of isolated carpal cartilages, and in regard to the relation between cartilage-isolation and ossification. In the case of cartilages which are usually separate being continuous on the surface but not in the depths, it may be that they are becoming confluent; but, as the instances above noted were in not full grown subjects, it may be inferred, rather, that separation was in progress. That the outlining of the cartilages should be antecedent to ossification is what we would expect from what we know in human osteogeny; and we see in Mysticetus the ulnare of the adolescent male, and, in the adult female, the left disto-carpal fully and the radiale nearly fully outlined, all without ossification. But we see the reverse in the adolescent male, in ossification having begun in the radiale without any, and in the disto-carpal with only partial, marking off from the epiphyses beyond them. It may be a matter of sex that in the adolescent male the metacarpal of the pollex and its supporting radiale are ossified while neither are ossified in the adult female; but the non-ossification of the ulnare in the adolescent, and of the left disto-carpal in the adult, seem to show that these are but instances of variation among rudimentary structures.[1]

IV. Comparison of other Bones and Cartilages of the Pectoral Limb in Mysticetus and Balænoptera Musculus.

As I embraced the opportunity of dissecting the cartilages of the digits as well as those of the carpus and prepared the bones of both the adult and the younger Mysticetus, I give here the measurements made and those of B. musculus for comparison, and what I noted of the cartilages and bones of the limb of Mysticetus. The scapula was not obtained. In the various communications above referred to I have given figures of the pectoral limb of B. musculus (loc. cit., 1871, fig. 1), of Megaptera (loc. cit., 1887, fig. 6), and now of Mysticetus (fig. 1), all of the same side

[1] It may be suggested as an interesting subject of research by some one who has the opportunities, to inquire into the order of appearance of separate carpal cartilages in cetacean embryoes and in the embryoes of some active-fingered mammals, and their relation to ossification; among five-fingered hands preferably the human.

for comparison. If these three figures are compared it will facilitate the study of the characters here described.

TABLE V.—*Giving, in feet and inches, the measurements of the Pectoral Limb and of the Bones of the Arm and Forearm of the 35-feet-long and 48-feet-long Mysticetus, and of the 50-feet-long B. musculus.*

	Mysticetus 35 feet.		Mysticetus 48 feet.		B. musculus 50 feet.	
	ft.	in.	ft.	in.	ft.	in.
Length from head of humerus, . .	5	6	8	7	5	11
Breadth, greatest, ...	2	...	4	6*	1	4
Humerus, length, ...	1	3¼	2	0½	1	5
,, greatest diameter of articular head, ...	...	7	...	11	...	8
Humerus, breadth of shaft, at narrowest part, ...	...	6	...	8½	...	6¾
Humerus, thickness at narrowest part,	...	3¾	...	6¼	...	4½
Radius, length along middle, . .	1	6	2	2½	2	2
,, ,, without carpal epiphysis,	1	4¼	1	11	2	...
,, breadth at proximal end, below epiphysis, ...	...	6	...	8½	...	6¼
,, breadth at narrowest part of shaft, ...	...	4¼	...	8	...	3⅝
,, thickness at narrowest part of shaft, ...	...	2	...	3½	...	2½
,, breadth at wrist, above epiphysis, ...	...	6¼	...	10¾	...	6¼
,, thickness at wrist, above epiphysis, ...	...	3⅛	...	5¼	...	3¼
Ulna, length along middle, . .	1	5½	2	1½	2	0½
,, ,, without carpal epiphysis,	1	3¾	1	10	1	11
,, breadth at proximal end, including bony olecranon, . .	...	5	...	8¾	...	6½
,, breadth at narrowest part of shaft,	...	2½	...	4	...	2½
,, thickness at ,, ,,	...	1¾	...	3	...	2¼
,, breadth at wrist, above epiphysis,	...	5¼	...	9	...	4⅞
,, thickness at ,, ,,	...	3	...	4½	...	1⅞
Width of interosseous space, at middle,	...	2	...	3½	...	2
Breadth of radius and ulna together at wrist, ...	...	11¾	1	7¾	...	11¼

Relative length of Arm and Forearm.—A contrast is seen, in the second and third columns of Table V., between the bones of the forearm in individuals of the two species of nearly the same length (48 feet and 50 feet), the one adult or nearly so, the other about ¾ grown. In Mysticetus, the whole paddle is much larger, over a third longer than and over thrice the breadth of that of B. musculus. In Mysticetus the humerus is much longer actu-

* Estimated. See Note in *Appendix* on breadth of the pectoral limb in Mysticetus.

ally, and slightly so in proportion to the total length of the paddle, than in B. musculus; the humerus in each being a little under ¼ of the entire length of the paddle. The forearm, on the contrary, is very nearly the same length in both; in Mysticetus, 2 inches longer than the humerus; in B. musculus, 9 inches longer than the humerus; in Mysticetus thus forming a little under ¼, in B. musculus a little under ⅓ of the entire length of the paddle.

The bones, more massive in Mysticetus, are seen in the Table greatly to exceed those of B. musculus in breadth and thickness. The greater width of the interosseous space further contributes to the greater breadth of the paddle in Mysticetus. When the two paddles are placed together, the greater proportional length of the forearm in B. musculus, and the greater massiveness of the bones in Mysticetus, at once strike the eye. The form of the ulna is very different; in Mysticetus expanding much more towards its distal end, and not curved towards the radius, but, on the whole, rather concave on its interosseous border.

Another marked difference between the two species is the greater length of the distal epiphyses of the radius and ulna in Mysticetus; averaging about 3½ inches in Mysticetus; in B. musculus only 2 inches at the radius, 1½ at the ulna. The greater length of the carpal epiphyses of the metacarpals is no less striking.

In my account of the Megaptera a comparison is given of various points in the anatomy of the digits with those of B. musculus (loc. cit., 1888, p. 254). The comparison, there, was between two great Finners, one with very long, one with shorter digits; here, the comparsion is between massive digits in a broad paddle and those in a narrower paddle with more slender digits. Various points of interest arise in conection with the proportions shown in Table VI.

Length of the digital region compared with that of the arm and forearm.—From Tables V. and VI. it is seen that the digits in Mysticetus are longer in proportion to the arm and forearm together than in B. musculus; in the adult Mysticetus the arm and forearm are, together, 51 inches in length, the longest digit 48; in the adolescent Mysticetus, the proportion is 33¼ to 32; while in the B. musculus, the proportion is 43 to 25½ inches.

TABLE VI.—*Giving, in inches, measurements of the Digital Bones and Cartilages in the 35-feet-long male and the 48-feet-long female Mysticetus, and in the 50-feet-long B. musculus.* c *signifies a cartilage;* × *signifies that the part was injured.*

Whale.	Mysticetus 35 feet long.					Mysticetus 48 feet long.					B. musculus 50 feet long.			
Digits.	I	II	III	IV	V	I	II	III	IV	V	II	'III	IV	V
Number of bones in each, . .	1	5	5	4	3	...	4	6	4	3	4	7	6	4
1st bone (metacarpal), length, .	$2\frac{1}{2}$	3	$3\frac{5}{8}$	$3\frac{3}{8}$	3	c	$5\frac{1}{4}$	6	$5\frac{5}{8}$	5	$3\frac{3}{4}$	5	$4\frac{1}{8}$	$3\frac{1}{8}$
,, ,, breadth, .	$1\frac{1}{8}$	$1\frac{5}{8}$	$1\frac{7}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	...	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{5}{8}$
,, ,, thickness, .	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{8}$	...	2	$2\frac{1}{2}$	$2\frac{1}{8}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{5}{8}$
2nd bone (1st phalanx) length, .	...	$2\frac{1}{2}$	$3\frac{1}{8}$	$2\frac{1}{2}$	$1\frac{7}{8}$	...	$4\frac{1}{2}$	5	$4\frac{5}{8}$	4	$3\frac{7}{8}$	$4\frac{1}{2}$	4	3
3rd bone ,, length, .	...	2	$2\frac{1}{2}$	2	$1\frac{3}{8}$	...	$3\frac{5}{8}$	4	$3\frac{3}{8}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{8}$	$2\frac{5}{8}$
,, ,, breadth, .	...	$\frac{9}{16}$	1	$\frac{9}{16}$	$\frac{3}{8}$	...	$1\frac{1}{8}$	$1\frac{1}{2}$	1	1	$\frac{5}{8}$	$1\frac{1}{8}$	1	$\frac{5}{8}$
,, ,, thickness,	...	$\frac{1}{2}$	$1\frac{1}{16}$	$\frac{9}{16}$	$\frac{5}{16}$	...	1	$1\frac{3}{4}$	$1\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{1}{4}$
4th bone ,, length, .	...	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{1}{8}$	...	...	2	$2\frac{3}{4}$	$1\frac{3}{4}$	...	2	$2\frac{1}{4}$	$2\frac{3}{8}$	$1\frac{3}{4}$
5th bone ,, length, .	...	$\frac{1}{4}$	1	...	...	...	...	2	...	...	...	$1\frac{1}{2}$	$1\frac{3}{4}$	...
6th bone ,, length, .	...	...	...	...	...	...	...	$1\frac{1}{4}$	...	...	...	$1\frac{1}{4}$	1	...
7th bone ,, length, .	...	...	...	...	...	...	...	...	...	...	...	×	c?	...
Terminal cartilage, length, . .	1	$1\frac{1}{4}$	$6\frac{1}{2}$	5	2	...	$1\frac{1}{4}$	$5\frac{1}{2}$	6	$\frac{3}{4}$	×	×	×	×
Total length, from carpus to tip of terminal cartilage, . .	$3\frac{1}{2}$ or 5	21	32	24	$14\frac{1}{2}$	7	30	48	36	21	$17\frac{1}{2}$	$25\frac{1}{2}$	23	$15\frac{1}{4}$
The bones together, length, .	$2\frac{1}{2}$	$9\frac{1}{4}$	$11\frac{7}{8}$	9	$6\frac{1}{4}$	...	$15\frac{3}{8}$	21	$15\frac{3}{8}$	$10\frac{3}{4}$	$12\frac{7}{8}$	$17\frac{7}{8}$	$16\frac{3}{8}$	$10\frac{1}{2}$
The cartilages together, including the terminal, ...	1 or $2\frac{1}{2}$	$11\frac{3}{4}$	$20\frac{1}{8}$	15	$8\frac{1}{4}$	7	$14\frac{5}{8}$	27	$20\frac{5}{8}$	$10\frac{1}{4}$	$4\frac{5}{8}$	$7\frac{5}{8}$	$6\frac{5}{8}$	$4\frac{5}{8}$

Thus, in Mysticetus, the digital part is more developed, relatively to the upper parts of the limb, than in B. musculus. The digits, however, are of the same relative lengths; digit III the longest in both, the order of greatest length of the other digits being IV, II, V.

Note to Table VI.

In *the 50-feet-long B. musculus* the 7th bone of digit III was injured, and the state of the terminal cartilages could not be ascertained. In the 64-*feet-long B. musculus*, the length of the 7th bone (the most distal ossification) in digit III was $\frac{3}{8}$ inch, that of the terminal cartilage 1 inch; in digit IV the length of the 6th (the distal) bone was 1 inch, that of the terminal cartilage 1 inch (loc, cit. 1871, p. 124, and figs. 1 and 2 there). In *the 65-66-feet-long B. musculus*, the bones in digits II, III, IV, V were, respectively, 5, 8, 8, 5 in number (loc. cit., 1887, p. 259); in its digit III the lengths of the 6th, 7th and 8th bones were, respectively, 2 inches, 1 inch, $\frac{3}{4}$ inch; in its digit IV the lengths of the same bones were, respectively, 2 inches, $1\frac{1}{2}$, and $\frac{1}{2}$ inch; the length of the 5th bone in its digits II and V were, respectively, $2\frac{1}{2}$ and $2\frac{1}{4}$ inches. The lengths of the digital bones, given in the Table, are taken along the middle and are $\frac{1}{4}$ to $\frac{1}{2}$ inch less than the extreme lengths, as the ends are generally concave.

Comparative breadth of the digital regions.—The very much greater breadth of the digital region in Mysticetus, besides that it commences from a much broader carpus, is owing partly to the moderate divergence of the three middle digits, but mainly to the great divergence of digit V. Thus in the adult one, the spaces on each side of digit III are, at the point of digit II, 4 inches; at the point of digit IV 7 inches; at the point of digit V the divergence from digit IV is 13 inches; and the presence of a pollex adds about 2 inches to the breadth; in the adolescent one $2\frac{1}{2}$ inches. But in B. musculus, digits II, III, and IV lie near each other naturally (see figs. 1 and 2, loc. cit., 1871) at their earlier parts, and converge at their tips so as almost to touch. Digit V rather slants towards digit IV distally, and at the tip is only $1\frac{1}{2}$ inches apart from it.

Number of ossified bones in each digit.—The number of ossifications, including the metacarpals, in digits II, III, IV, and V in the *adult* Mysticetus are, respectively, 4, 6, 4, 3; in this B. musculus, respectively, 4, 7, 6, 4. The greater number reached in my aged B. musculus is noted below Table VI. But taking even this 50-feet-long B. musculus, it is seen that the number of digital ossifications is not so great in Mysticetus as in B.

musculus (1 less in digit III, two less in digit IV, 1 less in digit V) although the digits are relatively longer in Mysticetus.

In the *adolescent* Mysticetus, the 6th ossification of digit III has not yet begun, but, at an inch beyond the 5th, the long terminal cartilage is segmented. The presence of a 5th ossification in digit II, not present in the adult, may be associated with the fact that the metacarpal of the pollex is ossified but not in the adult.

It may be that, had this adult Mysticetus lived on into old age, additional phalanges might have been formed by the subdivision and ossification of the long terminal cartilages; but, as this Mysticetus was adult and the B. musculus only $\frac{4}{5}$ grown, and as the aged B. musculus had as many as 8 bones in the two middle digits as in the long-fingered Megaptera, it appears right to conclude that the ossified phalanges are less numerous in Mysticetus than in the Finners.

Proportion of Cartilage to Bone in the digits.—The greater proportional length of the digits in Mysticetus is, therefore, made up by cartilage. In digits II and V of the adult, the cartilages together (including the proximal cartilages of the metacarpals) form almost half of the entire length of the digit; in digits III and IV considerably more than half, owing to the great length of the terminal cartilages of these two digits. But deducting these long terminal cartilages, as perhaps in part assignable to future ossification, nearly half of the entire length of digits III and IV is formed of cartilage. In the adolescent Mysticetus, it is seen in Table VI., that, even deducting the whole of all the terminal cartilages, the amount of cartilage is, in all the digits, greater than the amount of bone, except in digit V in which they are of equal amount, and in the pollex, in which they would be about equal had the proximal epiphysis of the Metacarpal been marked off from the radiale.

In contrast with this, in the *B. musculus* given in Table VI, the cartilages together form, expressed generally, little over a third part of the entire length of the digit. Some allowance has to be made for the want of the terminal cartilages which had been destroyed, but the proportion was fully ascertained in my 64-feet-long B. musculus (loc. cit., 1871, p. 124) in which the digits were entire and from measurements made at the dissection. The lengths of the terminal cartilages for digits II, III, IV, V, respectively, were $1\frac{1}{2}$, 1, 1, 1

inch. The proportion of bone to cartilage in the four digits, respectively in the same order, was $18\frac{5}{8}$ to $6\frac{1}{8}$ inches, 25 to $8\frac{1}{2}$, $22\frac{1}{2}$ to $8\frac{1}{2}$, 14 to 5.

In the *Megaptera*, in which the two middle digits are of vast length, the amount of cartilage, though greater than in B. musculus, still falls largely short of the amount of bone; the proportions of bone and cartilage in the four digits, stated in the same order, being, respectively, $26\frac{1}{4}$ to $11\frac{3}{4}$, $55\frac{1}{8}$ to $25\frac{7}{8}$, $46\frac{1}{8}$ to $33\frac{7}{8}$, $17\frac{7}{8}$ to $14\frac{5}{8}$ (loc. cit., 1887, p. 260). The proportion of cartilage to the entire digit, per cent., in Megaptera and in the 50-feet-long B. musculus, was, in the four digits, II, III, IV, V, respectively, in Megaptera 38, 31·9, 42·3, 45; in the 50-feet-long B. musculus 27·5, 29·9, 28·8, 31·1. The proximal epiphysis of the metacarpals is included in this estimate in all cases. Its length, in the adult Mysticetus, averages $2\frac{3}{4}$ inches, in the adolescent Mysticetus, $1\frac{1}{2}$ inches; in the 50-feet-long B. musculus, only $\frac{1}{2}$ inch.

Thus, while in the $\frac{4}{5}$ grown B. musculus, the cartilages formed under $\frac{1}{3}$ of the whole digit, and, in the full-grown B. musculus, only slightly over $\frac{1}{4}$ of the whole digit, they form in the adult Mysticetus $\frac{1}{2}$ or more, and in the adolescent Mysticetus, more than half of the whole digit. Considered functionally, this greater proportion of cartilage in the digits of Mysticetus might be regarded as an adaptation to greater flexibility, but, looking also to the same condition of the carpus, is perhaps to be regarded only as a less development of ossification in Mysticetus.

Relative length of the digital Bones.—It is seen in Table VI. that the digital bones decrease in length progressively. In the B. musculus an exception to this is seen in the first phalanx of digit II being slightly longer than the metacarpal; more marked in the aged B. musculus, in which the same applies also to digit V; and much more marked in all the digits of Megaptera, except in digit III, in which latter the two first bones shoot out a great length (loc. cit., 1887, p. 265). This comparison may seem a detail, but it brings out an interesting adaptation. These lengths in Megaptera enable the alternate nodes and hollows of neighbouring digits to fit into each other, and the same applies to a less extent to the earlier nodes in B. musculus; but, in Mysticetus, the greater breadth of the paddle and divergence of the digits renders such adaptation unnecessary. As seen in fig. 1, the first node of the great digit, III., lies almost opposite the nodes of the neighbouring digits and with space between.

Although the further nodes of the great digit are considerably beyond those of the neighbouring digits, this is owing simply to the greater size of the digit, no lateral fitting being possible to the widely separated digits of Mysticetus.

Form of the digital bones.—The most striking difference in form between the digital bones of Mysticetus and those of B. musculus is their much less hour-glass shape in the former, less contracted at the middle. The greater proportional *breadth* in Mysticetus is seen more especially in the metacarpals. In Table VI. it is seen that the breadth of the metacarpals taken at the middle of the shaft, is, in the adult Mysticetus, more than half the length of the bone, while the breadth is only about a third of the length in B. musculus, less than a third in the two great digits.

The measurements of breadth as well as length given of two of the digital bones in Table VI. are sufficient to indicate the greater *breadth* of the bones generally in proportion to their length in Mysticetus, but, as the measurements are taken at the middle of the shaft, they do not show the greatest breadth of the bones, which are much broader at the ends, owing to the hour-glass form. This may be illustrated by comparing the breadths at the ends with the breadth at the middle of the shaft in, for instance, the second bone of the great digit, III, in the two species. In the 48-feet-long Mysticetus this bone, with a length of 5 inches to a breadth of 2½ at the middle of the shaft, expands at the ends to a mean breadth of only 3½ inches; while in the 65–66-feet-long B. musculus the corresponding bone, with a length of 7¼ inches to a breadth of 1¾ at the middle of the shaft, expands at the ends to a mean breadth of 3¾ inches.

The digital bones are also *thicker* (palmar to dorsal measurement) in proportion to their length in Mysticetus than in B. musculus. In the case of the metacarpals, as seen in Table VI., this difference does not seem so very striking a character as their greater breadth. Comparing thickness with breadth, in the metacarpals, the thickness in Mysticetus is about ⅓ less than the breadth, but in B. musculus not nearly so much less than the breadth. In proportion to the length, the thickness of the metacarpals in Mysticetus, is, except on digit V, over ⅓, in B. musculus under ⅓. These measurements of the 3rd bone are given in the Table as an example of the phalanges generally. In Mysticetus, the thickness is seen to be about equal to the breadth, more in digits III and IV, less in digits II and V; in B. musculus, the thickness is less than the breadth in all the digits, This greater thickness as well as greater breadth of the digital bones in Mysticetus than in B. musculus, absolutely as well as relatively to the length, is part of the greater general robustness of the whole digit in Mysticetus.

ent of phalanges, as well as of other *limb-bones,* cular ends as compared with *the shaft, is not* nalian feature. The exaggeration *of this to the* on the digital bones of Fin-whales, and *more* aptera, affords recesses for lodgement, more or es of neighbouring digits. In cetaceans, the paddle, and consequently of the fingers, requires be mainly lateral, and hence it is seen strongly d dorsal aspects, but much less when seen edge- gers cannot move separately in a cetacean, the langes would seem not to require to be strong, o expand to support the great cartilaginous se nodes should be so large, so much broader the phalanges, is not evident, unless it is to firmness to the digital region of the paddle.

he Digital Joints and Cartilages

d here are—(1) the occurrence of more or less ecting the nodes: (2) the form, &c., of the rtilage of the nodes: (4) the terminal cartilage on it may present.

oted and figured in *B. musculus* (loc. cit., 1871, ce of a joint subdividing the cartilaginous nodes, ddle third of their breadth or less, seen on both the smaller nodes. In a toothed whale, *Hyperoodon* et long, in which I found rudimentary finger-muscles it better developed than in B. musculus, the nodes a cavity reaching completely across, but the surfaces 1873, p. 118). The digital region occupies about n of the paddle as in B. musculus. In *Megaptera* 254), in which the nodes are larger than in B. mus- ng smooth-walled synovial cavity reached across the except in the three distal nodes of the two great l node of digit V. In these it did not quite reach orsum or sides, the remainder of the separation being ving as a white line on section. The surface groove, on both aspects on these nodes also. The finger- alf the size of those of B. musculus, although the limb is much longer and larger than in B. musculus, udimentary nature. The tendons, by adhering to ligaments, and by traction on them the muscles l resistance.

here is the surface groove seen all round, bridged

over by fibrous tissue under the perichondrium, but there is no synovial cavity, only a thin layer of soft substance passing through and through the node, as seen in sections. To the naked eye this soft tenacious substance looks like fine fibrous tissue. Under the microscope, it is fibrillated without cartilage cells. It is easily torn, giving the appearance, then, as if a synovial cavity had existed. When this soft substance is scraped off with the knife, an even surface of cartilage is exposed, presenting a mottled appearance but no perforations. The surfaces at the joint are not quite flat; the proximal surface a little concave both ways, but mostly from edge to edge, the distal correspondingly convex. Movement may be made to take place at the joint towards either palmar or dorsal aspect, the surfaces gliding on each other, or by rotation. A joint was seen in all the nodes, though finer at the distal nodes. In regard to the strength of the finger-muscles, I found them "fully as much developed" in Mysticetus as in B. musculus; but that was in a paddle about a foot longer and with much more bulky digits than that of B. musculus.

(2) *The nodes* present considerable enlargement, but uniformly, not more to one side than the other, as seen strongly in Megaptera, where there is lateral packing of the digits. Between the first node of digit III and that of its neighbours, there is, in the adult Mysticetus, a space of 1 inch to the radial side, 1¾ to the ulnar side, and between all the other nodes the spaces are much wider than the nodes. The enlargement is at the edges much more than to the surfaces, as the nodes partake of the general flattened form of the paddle. Taken at the two first nodes, the lateral enlargement exceeds the breadth of the contiguous bones by ½ inch at the proximal and by about 1 inch at the distal end of the node. The enlargement towards the surfaces is about half of that. The first node of the great digit is 4¾ inches in length, 5 inches in breadth, 3½ in thickness. The nodes do not diminish in length in proportion to the phalanges. Thus, the lengths of the nodes of digit III of the adult Mysticetus were, successively, 5, 4, 3¾, 3, 3 inches, with terminal cartilage of 5½ inches; while the lengths of the preceding bones are, successively, 6, 5, 4, 2¾, 2, 1¼ inches; that is, the distal half of the digits has a larger proportion of cartilage than the proximal half, even without the terminal cartilage. The flattening of the nodes is more marked in the adolescent Mysticetus, giving them more of the flattened-barrel shape.

(3) The *cartilage of the nodes, on section*, shows the numerous blood channels, mainly continued from the ends of the bones, some from the perichondrium. In vertical transverse sections they appear mostly as rounded apertures, at distances of ⅛ inch or more; in horizontal sections, as parallel passages with frequent anastomoses. They go near the joint, within $\frac{1}{10}$ inch or less, becoming smaller there, but do not pass into it. The blood-vessels are seen in the channels, and, in torn surfaces, project as little tufts. Under the microscope, in transverse sections, the cartilage cells are seen to be arranged round the vascular canals, first in a narrow belt, like the bone cells round a Haversian canal, but soon radiate outwards in rows, with their long axis pointing to the vascular canal.

At the part next the bone there is (observed in the adolescent subject) a softer layer of cartilage, about ¼ inch in thickness, darker and softest nearest the bone. When torn from the bone, the latter is honeycomb-like, the raised bony ridges projecting into the cartilage. The more immediate uniting substance is fibrous under the microscope, with, apparently, calcareous particles. This is evidently the progressive ossification of the uncompleted end of the bone. But the great masses of cartilage forming the nodes do not ossify. I have never found them but of cartilage throughout in all the whalebone whales I have examined. In this respect the whalebone whales differ remarkably from the toothed cetacea, among which I noted (*Edin. New Phil. Journal*, 1863) the occurrence of a bony epiphysis at both ends of the digital bones.

4. *The Terminal Cartilage* has to be examined narrowly, and by section, for any indication of subdivision. These subdivisions may be interpreted either as being in progress, as a stage towards additional ossifications; or as embryonic, an inheritance from a more fully ossified adult condition, awaiting further ossification.

The *Megaptera* showed interesting illustrations of the subdivision, even with short terminal cartilages; one subdivision in that of digit III, in both paddles, by soft substance, incomplete transversely, in a cartilage 1¾ inches in length; one such in that of digit V, in the left paddle only, in a cartilage 2⅝ inches in length; two subdivisions in that of digit II, in both paddles, a broad cartilage 3 inches in length, neither complete transversely, both in part synovial. These were partly seen on the surface, but might have been overlooked if sections had not been made. That of digit IV was not subdivided, but the cartilage preceding it was not yet ossified. Further particulars are given in *loc. cit.*, 1887, p. 254, figs. 10, 11, and 12. Such concealed joints can be detected only by very careful examination.

In *Mysticetus* the terminal cartilages of digits III and IV are very long, those of the other digits short. In the *adolescent* subject, there was a subdivision only in that of digit III. the longest of the terminal cartilages, 6½ inches in length. The joint occurred at 1⅛ inch beyond the distal (the 5th) ossification, was marked by a surface-groove round and round, and passed through and through the cartilage. The part proximal to this joint was thickened, like part of a commencing node. The cartilage beyond the joint showed no ossification, remaining as a cartilage about the same length as that of its neighbour of digit IV and as that of digit III in the adult. Here we see digit III in progress towards being provided with a 6th ossification in the adolescent as it has gained in the adult subject.

There was an obscure appearance of some change in that of digit V, which was a longer cartilage than in the adult (2 inches against ¾ inch). It was at ¾ inch beyond the distal phalanx, but I concluded that it could not be taken as a genuine indication of subdivision. Both the adolescent and adult subjects have three ossifications in this digit.

There was no evident subdivision in any of the terminal cartilages in the adult subject. There did seem to be, in the two longer cartilages, a firmer part with softer cartilage behind and before, but the indication was too faint to be accepted as evidence of subdivision.

The lengths of the terminal cartilages are seen in Table VI. In the *adult* subject, those of digits V and II were short cones; the tip of V 5½ inches, that of II 9½ inches short of reaching the edge of the paddle. The long terminal cartilages of digits III and IV, respectively 5½ and 6 inches in length, were rounded and tapered gradually to a point, at last the size of an earthworm, and reached to within about 1 inch from their part of the end of the paddle.

In the *adolescent* subject the terminal cartilage of the pollex was thick and firm; those of digits III and IV were of great length, as in the adult; that of digit III, at first a little flattened from its greater size, tapered from the size of a little finger to that of a goose-quill. All of them, except that of the pollex, tapered to a narrow point, and, except at first that of digit III, were soft and flexible, like earthworms.

General Remarks.—As the cetacean pectoral fin exhibits a modification of the mammalian limb to an entirely aquatic life, we expect to find many of its parts in a more or less rudimentary condition. The activities of the limb take place from the shoulder joint, at which movements occur in all directions, by the action of great muscles connecting the humerus to the very large scapula and to the trunk; including the movements by which the paddle is rolled on its axis—the feathering of the oar—which, in a fully-acting limb, are further accomplished by the rolling movement between the bones of the forearm. The humerus and the two great motionless bones of the forearm, form a rod of support, carrying the limb from the shoulder. The digits shoot out and give length to the paddle, their ossifications

variably exceeding the usual mammalian number of a metacarpal and three phalanges; and are webbed to beyond the points, thus modified for locomotion or for balancing the body in the water. The masses of cartilage at the wrist and between the digital bones contribute to the length and give some flexibility, especially towards the end of the paddle. The elbow joint is synovial but allows of extremely little movement, and the remaining joints allow of still less movement. To have movable joints in a cetacean paddle would be like having joints in an oar. The muscles, beyond those of the shoulder joint, are reduced to vestiges in the whalebone whales; or, as generally in the toothed whales, have disappeared, leaving their tendons and aponeurotic parts along the digits and the forearm, with ligamentous function only.

In regard to the *carpus*, in the whales treated of in this paper, it may seem unsuitable to speak of cartilages, some of which are several inches in diameter, as rudimentary structures, even in a large whale; but the point is why this carpal mass should be subdivided into a series of separate cartilages, more or less ossified, corresponding to the functional bones in active-handed mammals. I have endeavoured to suggest various minor adaptations here and there of these cartilages, but these do not depend on the cartilage of the wrist being in separate pieces. The most evident is that of the pisiform cartilage, serving as a stretcher to the soft parts and giving breadth to this part of the paddle; but this does not depend on its being a separate cartilage, and it is not evident how the efficiency of an oar would be increased by one side of the blade being hinged. The elasticity of the pisiform projection would provide for any little yielding advantageous to the living form.

There are various degrees of rudimentariness among usually present structures, grading from those for which a certain evident amount of function remains, to those for which no utility in the body containing them can be assigned; as, among the cetacea, the transitory calcified teeth in whalebone whales that come and go before birth, or the persisting vestige of a thigh-bone in Balænoptera musculus (loc. cit., 1871, p. 107, fig. 3, and 1893, p. 291, and figs. 1 to 9), or of a tibia in Mysticetus (loc. cit., 1881, p. 141, figs. 1 to 18). The more full development of the carpal

bones in some of the toothed cetacea does not alter the bearing on the question of the origin of the species treated of in this paper. My conclusion, therefore, is that the presence of these carpal cartilages, as separate bodies, with their varying ossification, can be reasonably accounted for only on the hypothesis that they have been inherited from some pre-existing species in which they were functional.

APPENDIX.

External form of Mysticetus.

By the kindness of Captain David Gray, of Peterhead, so well known to have large experience in the Greenland whale fishing, I am able to give a figure (fig. 9) of the external form of *Balæna mysticetus*, which I received from him in 1886; and by the kindness of his son, my former pupil, Dr Robert Gray, a figure (fig. 10) of the form of the pectoral limb, which I received from him in 1887. The figure by Captain Gray is founded on numerous measurements made by him, and represents an average full-grown male Greenland Right-whale. The particulars of the figure are given with the explanation of the Plates, fig. 9.

Form of the Pectoral Limb.—The figure (fig. 10) is from a drawing made from nature by Dr Gray, who also has had considerable experience in the Greenland seas. It is from an unusually large female, 57 feet in length, described to me by Dr Gray as a magnificent female, the largest his father had ever taken. The great breadth of the paddle compared with that of the Finners is seen. *Length*, from the wrinkle of the skin where the paddle joins the body, 8 feet 2 ½ inches, the length being, therefore, greater than that of the one from which my figure (fig. 1) is taken, the measurement of which (8 feet 7 inches), is taken from the head of the humerus. *Breadth*, where the paddle joins the body about 4½ feet, greatest breadth 5 feet 1 inch. The greatest breadth is beyond the middle of the fin, and is evidently at about opposite the end of the very divergent digit V. The anterior border is seen to be uniformly convex; the posterior border very convex, till, on the distal fourth, it becomes concave, meeting the anterior in a pointed end. The concave part corresponds to where the digits fall away from the projecting digit V; the point corresponding to the end of digit III. The borders show no special projections corresponding to digit V, or to the thumb, the bones being covered thickly with blubber. Dr Gray mentions particularly, in his letter to me, accompanying the sketch and measurements

of the paddle, that the line of junction of the paddle to the body, marked by a wrinkle of the skin, is horizontal, as noted by him when the carcase lay with its back in the water, the paddles, both seen at the same time, raised by tackle, the palmar surface exposed to view.

Breadths as given in Table V.—As the skin and blubber had been removed from most of the paddles of my 48-feet-long Mysticetus, the breadth (4 feet 6 inches) allowed for them in Table V. is an estimate founded on Dr Gray's measurement, allowing for the greater size of the individual measured by him. Now, in the skeleton of the limb, from which fig. 1 is photographed, the greatest breadth, at the end of digit V, is only 3 feet, at the pisiform cartilage 2 feet 4 inches, but the bones are covered by thick blubber in the Mysticetus, unlike the Finners in which the blubber is thin, in Megaptera some of the nodes even bulging on the surface. In regard to the reliability of figures 1 and 2, although taken from the skeleton, I may mention that a paper shape was made of the position of the digits and their nodes as they lay during the dissections, and that all the bones were duly saw-marked, to guide us in articulation. The shape and measurements of the nodes were taken during the dissection, and are represented by wood in the articulated limb from which the photograph for the figure was taken. The great gap seen in the figures between the olecranon and pisiform projections was occupied by the ulnar fibrous curtain, and beyond this the convexity of the ulnar border was maintained by the thick blubber.

But in the 35-feet-long Mysticetus the blubber and skin had not been removed at the distal half, or more, of the paddle. The skin was probably somewhat dried, but the greatest breadth did not exceed 2 feet. This was at about the junction of the middle and distal thirds of the interval between the pisiform and the tip of digit V. It would seem, therefore, that, in this younger Mysticetus, the breadth of the paddle, in proportion to its length (2 feet to 5½ feet), was considerably less than that attained in the adult, as ascertained by Dr Gray (5 feet 1 inch to 8 feet 2½ inches); in the younger one, the breadth less than half the length; in the adult, more than half.

Measurements of a full-grown Mysticetus.—I may here add the measurements of a female *Balæna mysticetus*, given me by Captain David Gray, in 1885. Extreme length, 52 feet 9 inches; pectoral fin, length 7 feet 5 inches, breadth 4 feet 7 inches; extreme gape of mouth, 10½ feet; across lower jaw, 10 feet 2 inches; length of the whalebone, 11½ feet; head from tip of beak to eye, 18 feet; girth at eyes, 32 feet; girth at pectoral fins, 36 feet; girth at neck of tail 5½ feet; tail fin, 22 feet. A wooden model of this Mysticetus, scale 1 inch to the foot, made under the direction of Captain David Gray, was exhibited by him at the meeting of the British Association at Aberdeen in 1885, and may be seen in the Natural History Department of the British Museum, and an exact copy of it in the Anatomical Museum of Aberdeen University.

In "Notes on a Voyage to the Greenland Seas in 1886" (*The Zoologist*, April 1887) Dr Gray mentions, as the result of his father's comparison of some 200 Right-whales he has captured, in the Greenland Seas and in Davis Straits, that the average length of the full-

grown male is 51 feet. The average of the pectoral fin he gives as 7½ feet in length by 5 feet in greatest breadth.

Some have the impression that the female attains a greater length than the male, which others doubt. There are, probably, individual variations in both sexes as among other animals.

EXPLANATION OF PLATES II., III. AND IV.

PLATE II.—Fig. 1. Pectoral limb of the 48-feet-long *Balæna mysticetus*; left side, palmar surface. Scapula not represented. From a photograph, natural length 8 feet 7 inches, here reduced to about $\frac{1}{17}$. Bones light, cartilages dark. Humerus *H*; *R*, radius; *U*, ulna; *o, c*, olecranon cartilage, probably a little shrunk; *ep, r*, cartilaginous epiphysis of radius, showing part of its ossification on the surface; *ep, u*, same of the ulna. *Carpus*, the surface furrows outlining the carpal cartilages are seen; see the lettering and explanation of fig. 3. Ossifications of intermedium and ulnare seen on the surface. The digits, I, II, III, IV, V. Digit I, the pollex, one continuous cartilage, and not entirely separated from the radiale. Digit II, 4 ossified bones; digit III, 6 ossified bones; digit IV, 4 ossified bones; digit V, 3 ossified bones. The proximal cartilaginous epiphyses of the metacarpals dotted lightly; the cartilaginous nodes of the digits dotted dark, all subdivided by the furrow indicating the joint at the middle. Digits III and IV seen to have long tapering terminal cartilages.

Fig. 2. Pectoral limb of the 35-feet-long *Balæna mysticetus*, right side, seen on dorsal surface. From a photograph; natural length 5½ feet, here reduced to about $\frac{1}{17}$. For lettering and explanation of the parts, see figs. 1 and 3. No ossifications showed themselves on the surface of the carpus. The metacarpal of the pollex is seen to be ossified. In the other digits the number of ossified bones is seen to be, in digit II, 5, being one more than in the adult, fig. 1; in digit III 5, being one less than in the adult, but a dividing joint is seen near the beginning of the long terminal cartilage; in digit IV, 4, and in digit V, 3, being in both the same as in the adult. Digits III and IV seen to have long tapering terminal cartilages.

PLATE III.—The six figures on this plate are photographed from large drawings from nature by the author, arranged similarly on one sheet so as to bring them together for comparison. They are not all reduced to the same size—thus:—In the original drawings figs. 3, 4, and 5 are half the size of nature; fig. 7, two-thirds; figs. 6 and 8, full size. From these different sizes they have all undergone the same reduction in being photographed. In these six figures the bones are in outline only, the carpal cartilages dotted dark; the cartilaginous epiphyses dotted lightly. The three figures to the left of the observer are of the Greenland Right-whale, *Balæna mysticetus*; figs. 3 and 4, the left and right carpus of the adult; fig. 5, the right carpus of the

younger Mysticetus. Of the three figures to the right, the two upper are of the great Razor-back Fin-whale, *Balænoptera musculus*; the lowest is of the Lesser Fin-whale, *Balænoptera rostrata*.

Fig. 3. Section of left carpus, &c., of the adult Mysticetus, palmar view of posterior half of the section; reduced to about $\frac{1}{12}$. Radius, *R*; *ep*, its epiphysis, with contained ossification; *U*, ulna; *ep*, its epiphysis, with contained ossification; ossification of ulnar epiphysis seen to be larger than that of radial epiphysis. *Carpus*, the intersecting lines are the lines of articulation, by fibrous tissue, isolating and uniting the cartilages. First row, *r*, radiale, partially continuous with cartilage of pollex; *i*, intermedium, seen to ascend partly between radius and ulna. Radiale and intermedium seen not to articulate, connected only by a fibrous commissure; *u*, ulnare; *p*, pisiform, seen not to articulate with the ulnare. For second row, only one large cartilage, *d*, *c*, seen to articulate more or less with three digits, II, III, and I; the ulnare seen to articulate more or less with three digits, IV, V, and III. Digit I, the pollex, composed of one undivided cartilage. II, III, IV, and V, the metacarpal bones of these digits, the proximal cartilaginous epiphysis of each dotted lightly.

Fig. 4. Section of right carpus, &c., of the same; dorsal view of anterior half of the section. See the lettering and explanation of fig. 3. Cartilages the same as in fig. 3. *Ossifications* not the same in left and right carpus; ulnare and intermedium ossifying in both, disto-carpal ossifying only in right carpus, fig. 4.

Fig. 5. Section of right carpus, &c., of the adolescent Mysticetus, viewed as in fig. 4; reduced to about $\frac{1}{12}$. The differences from the adult, figs. 3 and 4, are seen to be, no ossification as yet in epiphyses of radius and ulna; no ossification in the ulnare; an ossification in the radiale; metacarpal of digit I, *m*, well ossified; terminal cartilage of this digit seen; no separation between radiale and a proximal epiphysis to metacarpal bone of digit I; disto-carpal partly continuous with cartilaginous epiphysis of digit II; radiale and intermedium articulate broadly with each other.

Fig. 6. Section of left carpus, &c., of the 45-feet-long ($\frac{4}{5}$ grown) *Balænoptera musculus*, palmar view of posterior half of the section; reduced to about $\frac{1}{6}$. Radius, *R*, with its epiphysis, *ep*, containing ossification; *U*, ulna, with its epiphysis, *ep*, containing ossification; ossification in radial epiphysis the largest. *Carpus*, the intersecting lines are the fibrous sutures, isolating and uniting the cartilages; the number and extent of the articulations of each cartilage are seen. First row, *r*, radiale; *i*, intermedium, seen not to articulate with the ulna; *u*, ulnare, seen to articulate also with the radius; *p*, pisiform, seen to articulate with the ulnare and narrowly with digit V; form of pisiform different from that of Mysticetus. Second row, two cartilages, *3*, radial disto-carpal (carpale III); *4*, ulnar disto-carpal (carpale IV). All of these cartilages well ossified, except pisiform not at all; radial disto-carpal the smallest ossification. II, III, IV, V, metacarpal bones of the four digits present in fin-whales; the carpal epiphysis of each metacarpal, dotted lightly, seen to be separated from each other and from the carpus by fibrous suture; the wrist joint

also only a fibrous suture; no synovial cavity anywhere in these localities in B. musculus or in Mysticetus.

Fig. 7. Left carpus, &c., of aged *B. musculus* (65-66-feet-long), palmar surface, reduced to about $\frac{1}{8}$ to $\frac{1}{9}$; drawing from the skeleton, the cartilages gone, but the bones articulated in natural position. Radius, *R*; *U*, ulna; their epiphyses mostly ossified and consolidated, grooves remaining at the places of union. *Carpus*, first row, *r*, radiale; *i*, intermedium; pisiform gone. Second row, *3* and *4* the two usual disto-carpals united on the surfaces into one bone, notches and median groove seen at middle where union has taken place; *2*, small additional disto-carpal ossification (carpale II, trapezoid bone) opposite metacarpal of digit II.

Fig. 8. Left carpus, &c., of 16-feet-long (half-grown) *Balænoptera rostrata*; reduced to about $\frac{1}{6}$; palmar view, the ossicles fully exposed. Radius, *R*, ulna, *U*, their epiphyses not begun to ossify. *Carpus*, same cartilages and ossifications as in B. musculus, fig. 6; same articulations of each cartilage, except that intermedium articulates in part with ulna; *p*, pisiform of different shape from that of B. musculus. Radial disto-carpal seen to have the smallest ossification, as in B. musculus, fig. 6.

Plate IV., fig. 9, from a drawing of a 50-feet-long male *Balæna mysticetus*, by Captain David Gray, of the "Eclipse," Peterhead; made from measurements taken by him. White parts are seen, below the mouth, with dark patches; at the eye, and leading forwards from it; on the shoulder and anterior edge of the pectoral fin; and at the narrow part in front of the tail fin (the dark part there is shading); the colour greyish below the body. The pectoral fin is not seen in full breadth, being to some extent in profile. Tail fin 22 feet transversely. The blow-holes are at the high part of the head, "the crown." The contour is seen to be concave, above and below, behind the head. The low position of the eye is seen, and the orbital projection. The position of the rudimentary ear-hole, between the eye and the shoulder, is not seen in the dark shading. The follicles of the hairs of the beard, better developed in the fœtus, are seen on the point of the beak and along the lower lip.

Fig. 10. Pectoral limb of a full-grown *Balæna mysticetus*, palmar surface; from a drawing made from nature by Dr Robert Gray, here reduced to about $\frac{1}{10}$. The true proportions are seen; its great breadth, 5 feet 1 inch; its length, 8 feet $2\frac{1}{2}$ inches, from where it joins the body.

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NOTES ON THE CHEMISTRY AND COAGULATION OF MILK.

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UPON the suggestion of Prof. M'Kendrick, I recently made a number of experiments with the view of clearing up one or two points in the chemistry of milk, upon which there is not yet unequivocal teaching.

The first question I proposed to myself was—Is there any *physical* difference between the clot obtained by acting on milk with rennet, and the precipitate got by acting on milk with an acid, *e.g.* acetic or hydrochloric?

According to present views, *e.g.* those of Halliburton, rennet changes the soluble caseinogen of milk into the insoluble casein by a process of true coagulation (not merely precipitation), whereas an acid merely *precipitates* caseinogen in such a manner that it is still possible, by proper methods, to cause this precipitate to be coagulated into casein.[1]

At present, and for the sake of brevity, we shall speak of the rennet clot and the acid precipitate.

NAKED EYE AND TACTILE PHYSICAL EXAMINATION.

The *clot*, on handling, seemed to have more internal cohesion, to be tougher, and to be notably more jelly-like in "feel" than the precipitate.

The *precipitate* seemed to have less cohesion, to be softer, to have less elasticity, to be more yielding to the touch. Passed between finger and thumb, the precipitate felt more granular, particulate, or discontinuous, though "finer in the grain" than the clot—*i.e.* the clot felt smooth and continuous till increased

[1] Dr Sidney Ringer, however, regards the action of rennet as a precipitation—the nature of which will be alluded to subsequently. *Cf.* Ringer in *Jour. of Phys.*, vol. xii., 1891.

pressure broke it up between the fingers, when, of course, it was dispersed, but in comparatively large fragments.

These examinations were made after each substance had been an equally long time prepared, *i.e.* one was not allowed to be more contracted than the other, for both contract slowly but steadily after formation.

Microscopic Examination.—On attempting to squeeze down a fragment of each under a cover-glass, the clot was more elastic, *i.e.* tended to recover its shape or had more resiliency than the precipitate; yet both were remarkably alike under high power.

Without having been previously told which was which, it would have been, I think, impossible to distinguish the one from the other. Both were granular, the numerous fat globules being very conspicuous, and I could not say that the clot showed any appearance of a *fibrous* structure.

Varieties of Clots.—I have found the greatest possible differences as to the characters of coagula formed under different conditions. The familiar typical clot of fresh milk, which (like blood-clot) at first quite fills the vessel and takes its shape, is best described as jelly-like—it resembles a jelly that has not yet "set"; it, however, contracts from the moment of formation, and in about half an hour has expressed a slightly turbid yellowish fluid ("whey"). This fluid only filters clear after two or three filterings through a single layer of paper. Its turbidity is due to fat globules not entangled by the clot; the clearest whey, therefore, is obtained by disturbing or breaking up the clot as little as possible so as to allow it to entangle and retain in its meshes the largest number of fat globules. The form of a clot is best seen, even by the experimenter, while it is the only way of showing it to a large number of people, by throwing the clot from the vessel where it is formed into a tall cylindrical glass of cold water. Many of its properties are thus displayed as it sinks slowly through the clear fluid.

Some clots are quite shreddy or flaky, *i.e.* formed of almost isolated flakes, while others of this class show more internal cohesion, and resemble an open felt-work. When the flakes are more elongated, the clot is "stringy." The clot formed of masses or *curds* of some considerable density is another and distinct form.

There is, lastly, a peculiarly *open*, snowy, precipitate-like clot, which has a great attraction for the sides of the vessel; it appears in fluids in which the substance to be coagulated is fairly dilute, *e.g.* when rennet is added to a *weak* solution of Ringer's caseinogen.

Saturation of Milk by Neutral Salts.

According to Halliburton, "caseinogen may be *precipitated* . . . by saturation with neutral salts. . . . This, however, is *not* coagulation, but precipitation."[1] "This process is a striking one. When you have added a large quantity of the crystals of $MgSO_4$, and shaken the mixture sufficiently, you find a separation as follows: caseinogen, as a granular precipitate entangling the fat globules, *rises to the surface* of a clear "whey" over a copious sediment of undissolved sulphate of magnesia.

This precipitate may be filtered off, and the filtrate is a dense pellucid fluid, "the salted whey."

Now, Prof. M'Kendrick suggested that this action of crystals of $MgSO_4$ might be purely a mechanical one, due to their presence as particulate matter. He therefore advised me to add a large quantity of some perfectly *inert powder*, *e.g.* powdered glass, and agitate milk with that. I accordingly added to ℥ iv. of milk ℥ ii. of powdered glass, and shook up the flask very thoroughly. I then attempted to filter the mixture, but found that it practically would not filter,—it filtered with excessive slowness; the filtrate was quite "milky," and clotted well with rennet.

The filtrate from "saturated" milk runs through fairly quickly, is strikingly clear, and will not coagulate with rennet. Powdered glass, as far as I could discover, had no action at all, mechanical or otherwise, on milk, and there is thus the highest probability that the action of salts, added to saturation, is a *chemical* and not a mechanical one.

The Reaction of Milk and its Coagulability.

Fresh country milk is said to have an alkaline reaction. Neutral milk (bought in town) clotted with rennet quite nor-

[1] *Essentials of Chemical Physiology*, p. 32.

mally. Faintly acid milk (town milk) did so similarly. Distinctly alkaline milk (made so by adding a few drops of strong KHO to ℥iv. of milk) did not clot with rennet, even when kept at 40° C. Distinctly acid milk (made by adding a few ♏ of glacial acetic acid to ℥iv. of milk) clotted quite well with rennet.

It is stated that milk diluted with ten times its bulk of water and then *neutralised* with dilute acetic acid "will yield no precipitate, as the casein (caseinogen?) is prevented from being precipitated by the presence of alkaline phosphates."[1] Thus, then, the "clotting" of *neutral* milk by rennet would seem to be a process different from precipitation, so far as the reaction of the fluid is concerned. The ferment rennin does not seem to be *destroyed* by—(*a*) weak acetic acid; (*b*) strong acetic acid; or (*c*) strong alkali (KHO). In support of *a*, besides my own experiments, Ringer finds[2] that slight acidity, such as is caused by two drops of 2 per cent. acetic acid in 10 c.c. of milk (too small to cause precipitation) accelerates clotting by rennet.

In support of *c*, the following experiment may be quoted:—Milk rendered distinctly (not excessively) alkaline by KHO, as above, would not clot with rennet even at 40° C., but on *neutralising* by acetic acid a clot was formed. Thus the alkali inhibited, but did *not destroy*, the power of the ferment. Thus we may say acids accelerate the action of rennin, while alkalies inhibit, though they do not destroy it.

Alkalies, on the other hand, appear to prevent the neutralisation-precipitate of caseinogen (regarded as an alkali-albumin), whose precipitation at neutralisation is postponed until there be free acid enough to convert the basic into acid phosphates.

Decalcified Milk.—It is well known that blood, to which a dilute solution of potassic oxalate has been added, will not coagulate, though it be kept for many weeks. This is, of course, due to the precipitation by the K-oxalate of the very minute quantity (·0311 per cent. in plasma) of calcic phosphate present in blood—calcic oxalate being formed. Can we produce a similar result with milk? I believe we can.

To 20 c.c. of neutral milk I added 10 ♏ of a 1 per cent. solution

[1] Stirling's *Outlines of Pract. Phys.*, p. 89.
[2] *Jour. of Phys.*, vol. xii. p. 169 (1891).

of potassium oxalate, then a few drops of rennet, and kept the beaker at 40° C. for some time: there was not the slightest appearance of clotting, not even a shreddy clot. When, however, 10 ♏ of a 10 per cent. solution of $CaCl_2$ was added to this beaker, a clot appeared in the course of half a minute.

Thus decalcified milk will not coagulate with rennet, showing that the presence of minute quantities of calcic salts are necessary for that process. The analogy with blood is complete.

Will decalcified milk, however, allow caseinogen to be precipitated by *acetic acid*?

The answer is, Yes, in precisely the same fashion as normal milk: acidulated decalcified milk yields a full precipitate of caseinogen.

We have in this reaction a striking difference between coagulation and precipitation of caseinogen.

The "Scum" in Boiling Milk.—Milk, though it will not coagulate or give any precipitate on boiling, yields a "scum" or pellicle of a solid material.

What is it chemically?

(1) Halliburton says it is lact-albumin.

(2) Stirling calls it "casein."[1]

As to (1).—The pellicle can be ground up in lime-water, with which it forms a kind of emulsion: if, to this fluid, rennet and a little phosphoric acid be added, we have a *clot* on heating. Thus it would appear *not* to be lact-albumin, at least not so entirely, as lact-albumin is a constituent of whey expressed from rennet clot, and it does not itself coagulate with rennet.

It is therefore *precipitated* caseinogen: casein, in the strict sense of its being caseinogen rennet-coagulated, it cannot be; and Halliburton says caseinogen is *not coagulated* by heat. The mere fact that the "scum" can be made to give a true "*clot*" points to its being precipitated caseinogen, which (just like the saturation-precipitate by $MgSO_4$) entangles fat, and *rises* instead of falling.

But by adopting Ringer's view, that all solidification of caseinogen is essentially of one kind, viz., a precipitation by combination with some calcic phosphate, we may say the heat has caused a certain amount of the phosphates to be precipitated,

[1] *Outlines of Pract. Phys.*, p. 91 (1890).

and that has united with a little caseinogen to form a solid pellicle ("casein" of Ringer): hence it is that milk, previously boiled, is more difficult to coagulate with rennet than is unboiled milk, because some of its calcic phosphate, having been in this way thrown down, is therefore not available for combining with the proteid. The scum, on this view, is then *precipitated* caseinogen ("casein" of some), but not casein if by that is meant the product of enzyme-coagulation.

The Fat of Milk.—The presence of fat in milk has usually been demonstrated by adding potassic hydrate to dissolve the albuminous envelope of the fat globules, and then shaking up with ether, dissolving out some of the fat, which, if thrown on paper, will give the "grease-stain." But fat in milk may be also demonstrated rather strikingly by merely adding to the milk one-quarter its volume of a 1 per cent. solution of osmic acid, and in a few minutes *the whole mass will have become black.*

For the demonstration of lactose, lact-albumin and chlorides in whey use the whey after saturation with $MgSO_4$.

The whey obtained in other methods is frequently so turbid from unentangled fat-globules that the "salted whey" has the advantage, to begin with, of *perfect transparency.*

When a little is added to boiling Fehling, there is, of course, a precipitation of earthy phosphates, but the colour of the cuprous oxide can be quite well discerned.

The lact-albumin is well demonstrated by the xanthoproteic reaction in "salted" whey.

The inorganic salts may be demonstrated in the usual manner. For class-purposes the use of a *transparent* whey is very desirable.

THE TEMPERATURE OF THE ACTION OF RENNET.

Is there any evolution of heat attending the chemical changes constituting the action of rennet?

I tested this point in the following manner:—Two specimens of milk, about ℥vj. each, were kept at the temperature of the laboratory, viz., 10·38° C., at which they remained for four or five hours.

To one of them I added very cautiously ʒ i. of rennet, and stirred the whole once very slightly.

In half an hour the thermometer in this glass (a very finely graduated one) had risen to 10·8° C., an increase of ·42° C., which was maintained for about an hour, after which the temperature fell.

Of course the milk never clotted, as the temperature was too low, and to have heated the mixture would have destroyed the test as arranged; but, upon Ringer's view, the rennet was changing the caseinogen into casein (even *before* the visible coagulation), which he regards as a *precipitate* of caseinogen with lime—a compound more sol uble at 0° C. than at 40° C.

THE COMPARATIVE QUANTITIES OF CALCIC PHOSPHATE IN VARIOUS KINDS OF WHEY AND IN MILK.

(1) If there is a using-up of calcic salts of phosphoric acid by rennet coagulation, we should find that there is less earthy phosphate in rennet-whey than in milk. With a view to analysing each of these, I took ℥ iv. of milk, and added ʒ i. of rennet, and, having let it clot at 40° C., filtered off the whey, which was then tested quantitatively for earthy phosphates. The following were obtained:—

Phosphate of calcium and phosphate of magnesium constitute at least 45 per cent. of the *ash* of milk.

These salts are very nearly 25 per cent. of the ash of rennet-whey.

∴ there *is* less earthy phosphate in the latter; and the difference, 20 per cent., is a measure of the amount of soluble salt which has become insoluble during the coagulation, and united with caseinogen to form casein.

(2) As to the relative amount of earthy phosphate in rennet-whey and in acid-whey.

Since the presence of calcic phosphate seems essential to clotting of caseinogen by rennet, and is not essential to the precipitation of it by acetic acid, we should expect that the ferment would use up a greater amount of the salt than the acid does. This is so. ℥ iv. of milk were taken in both cases.

Calcic and magnesic phosphates in acetic *acid-whey* are *38* per cent. of the ash.

Calcic and magnesic phosphates in rennet-whey are 25 per cent. of the ash.

This acid-whey has 13 per cent. more of earthy phosphate than rennet-whey has; that is to say, while coagulation of caseinogen means a *union* of the proteid with the calcic salt, the precipitation of caseinogen has not involved the disappearance of anything like so much salt: indeed, we have had evidence already that the precipitation can proceed in entirely decalcified milk.

The Resolution and Re-coagulation of Casein.

The clot obtained by the action of rennet on milk is *casein.*

I asked myself the question, "Can this clot be dissolved; and if so, can it be re-coagulated by rennet?" If the answer to this is affirmative, then casein differs markedly from fibrine (which *cannot* be re-dissolved as fibrinogen and be re-coagulated); whereas it resembles myosin, which *can* be re-dissolved and re-coagulated.

Casein obtained by rennet from neutral milk was allowed to stand until it had squeezed out its whey.

It was then thrown into a mortar and ground up with three or four times its vol. of distilled water: of course it did not "dissolve" in this in a strict sense, but formed a fine creamy fluid or suspension, in which there was very little tendency for the casein to separate: it resembled an emulsion, and was very similar to the fluid obtained when you dissolve the acetic acid precipitate of caseinogen in lime water. Call it A.

(1) A+rennet+heat at 40° C. yielded an excellent clot. From this alone we conclude there was enough calcic salt in solution to suffice for successful coagulation by the rennet.

Thus the question can be answered in the affirmative; and as I repeated the operation three times (re-dissolving and re-coagulating the casein three times), apparently the process can go on *ad infinitum.* I tested all clots by throwing them into a tall vessel of water, whereby they can be at once distinguished from mere precipitates, which, however dense, *cannot cohere* in

[1] *Jour. of Phys.*, vol. ii. (1890).

their fall through the water, but open out as particulate deposits; whereas *clots*, though they may break up, yet fall as masses, with a certain degree of internal cohesion: they are *masses*, not merely particles.

I believe this a most important test of a clot, especially if there be little of it.

I noticed several curious facts about fluid A.

(2) Fluid A. *heated to* 40° C. *clotted*, in part, apparently spontaneously. This I can only explain by supposing that in fluid A. there was some unaltered or still functional rennin present.

(3) To some of A. a few drops of ·5 per cent. phosphoric acid were added, and beaker heated to 40° C., when a much better clot than in (2) was obtained. Here no rennet was added.

(4) To some of A. a few drops of 10 per cent. $CaCl_2$ sol. were added, and the whole heated to 40° C., when a clot equally as good as in (3) was obtained: indeed, clots (3) and (4) were equal to the clot of (1) in consistency.

(3) and (4) I can only explain in the same way as (2).

The next is rather curious:

(5) A + ·5 per cent. phos. acid + 10 per cent. $CaCl_2$, all heated to 40° C., yielded an open granular clot of less consistency than any yet obtained.

In the next two the order of addition of reagents is to be noted:

(6) A + R[1] + phos. acid. + $CaCl_2$ + heat gave a very poor clot; whereas—

(7) A + heat + phos. acid + $CaCl_2$ + R, an exceedingly copious clot.

At present I can arrive at no *explanation* as to how *the order* of introducing these substances affects to such a degree the quality of the clot. Rennet[1] added late gave the better clot.

II. If we now turn to the precipitate of caseinogen by acetic acid, we shall find that it may, after being washed to get rid of excess of acid, be "dissolved" in CaH_2O_2.

It forms a creamy fluid of the appearance of a suspension or emulsion. Call it D.

[1] R everywhere stands for *rennet*.

(1) D+rennet+heat to 40° C. gave a poor, shreddy clot; whereas—

(2) D+rennet, heated as before, yielded a splendid clot as soon as a few drops of phosphoric acid were added.

The next is a striking reaction:

If D. be *decalcified* (by adding potassic oxalate to it), and then heated with rennet, there is no clot; if *to this mixture* some $CaCl_2$ be added, a clot at once appears.

III. Ringer's caseinogen, prepared from neutral milk according to directions in *Halliburton's Elements* (pp. 119 and 120), yields an opalescent solution. Call it C.

(1) C+rennet+heat, no coagulum, but on adding $CaCl_2$ a good clot.

(2) C+phos. acid+heat, no clot; add rennet, slight clot; add $CaCl_2$, when a rapid intensification of density of clot appears.

From these and other experiments it appears the calcium has more to do with successful clotting of milk than the phos. acid has: with this Ringer entirely agrees.

(3) Ringer's caseinogen boiled yields no ppt. or coagulum; merely a slight yellow discoloration.

It soon becomes putrid, an acid reaction supervenes, and a certain amount of precipitation takes place.

(4) C+rennet+heat, no clot; +phos. acid, no result, presumably from lack of calcium.

IV. Taking now the magnesium sulphate saturation—precipitate which is really caseinogen with entangled fat and much $MgSO_4$. Call it B.

(1) B+water+rennet+heat, a fairly good clot.

(2) B+water+R+heat, a clot as in (1); add phos. acid, and at once the clotting is greatly intensified.

(3) B+phos. acid+heat, no clot; +$CaCl_2$, no clot; +rennet, a badly formed clot.

(4) B+rennet+$CaCl_2$+heat, no clot; +phos. acid, at once a clot is formed.

Here rennet added early gave the better clot.

Reasons for believing, with Halliburton, in the *non*-identity of *caseinogen*, the proteid precipitated from milk by an acid or by saturation with a neutral salt, and *casein*, the proteid coagulated by rennet.

(1) Decalcified milk will not coagulate with rennet, but will yield a precipitate of a proteid with an acid.

(2) A substance can be prepared from milk by precipitation by an acid, or by saturation with a neutral salt, which, in the presence of calcic phosphate, will clot with rennet.

(3) There is 13 per cent. more of calcic phosphate used up in rennet-coagulation than in acid precipitation:—an indication that these are chemically distinct processes.

(4) There is some physical difference between the precipitate and the clot.

Classification of Similarities between Blood and Milk.

(1) *Both* have a plasma in which are solid particles.
Blood has red discs, leucocytes, and blood-plates.
Milk has fat-globules and colostrum corpuscles (sometimes).

(2) Both contain representatives of each of the Food-Stuffs—
Proteid, Fat, Carbohydrate, Salts, Water.

Blood has	Fibrine, &c., globulines and serum-albumin.	Fat.	Dextrose.	NaCl. $CaCl_2$.	Water.
Milk has	Caseinogen and lact-albumin.	Fat.	Lactose.	$CaHPO_4$. $CaCl_2$.	„

(3) Both fluids coagulate by an enzyme, the clot entangling the solid bodies being jelly-like, and at first quite filling the dish, but contracting and expressing *serum* and whey respectively.

(4) *Decalcification* of each prevents clotting.
∴ clotting depends on the presence of minute quantities of calcic salts.

In blood ·0311 per cent. of *plasma* is calcic phosphate.

In milk ·6 per cent. is inorganic salts, chiefly calcic phosphate.

(5) In both, *Heat* is given out during coagulation.
„ a *Low temp.* retards coagulation.

(6) "Analysis of *ash* of milk is very similar to that of blood corpuscles" (M'Kendrick).

(7) *Blood* is alkaline.

Milk, human and bovine, when quite fresh, is alkaline (or neutral).

(8) The colour of both is due to solid particles, not to the fluid, and to the *scattering* of the light by the opaque red discs and fat globules respectively.

(9) Acids and alkalies destroy the suspended particles in each fluid.

(10) Whey, like serum, contains a sugar, salts, and a soluble proteid (lact-albumin and serum-albumin respectively).

Dissimilarities between Blood and Milk.

(1) Blood has all its factors for clotting within itself, milk has not.

(2) Milk is a "Perfect Food": blood is not.

(3) Blood-clot has fibres in a felt-work, curd has no visible fibres—it is molecular.

(4) Fibrine cannot be dissolved and re-clotted *ad inf.*, casein can.

(5) The particles suspended in milk are specifically lighter than the fluid.

∴ milk has a less spec. gravity than the fat-free "milk," viz., sp. gr. of *milk* 1025–1030; while fat-free milk is 1033–1037.

The particles (red discs) in blood are specifically heavier than the fluid plasma (which is 1026–1029), being 1105. Sp. gr. of *blood* 1055.

Milk minus solid matter is specifically heavier than before.

Blood minus solid mater is lighter than before.

(6) The pigment of blood is a proteid.

„ „ milk is a lipochrome.

(7) The boiling of milk still leaves it liquid; blood would coagulate before 100° C.

My thanks are due Mr William Lang, B.Sc., of the Chemical Laboratory in the University, for having assisted me in several of the qualitative estimations.

A CONTRIBUTION TO THE MORPHOLOGY OF THE PROSTATE. By C. Mansell Moullin, M.A., M.D. Oxon., F.R.C.S. Eng., *Surgeon and Lecturer on Physiology to the London Hospital.*

The prostate is one of the accessory male organs of generation, and is situated on the outer and posterior aspect of the ejaculatory ducts at their termination in the urethra. The glands of which it is composed open into the first portion of the urethra, but the prostate has nothing to do with micturition, and its connection with the urethra is entirely secondary.

The prostate is a paired structure, like the testes and the vesiculæ seminales. In many of the vertebrata it consists of two distinct bodies, one on each side, corresponding to the vasa deferentia, and, like them, separate from each other throughout life. In the human embryo the arrangement is almost the same. Later in the course of development, and in correspondence with the principle of lateral fusion from below upwards that holds good of so many of the organs of generation (notably those formed from the ducts of Müller), the two portions coalesce. So far as the inferior extremities are concerned, the fusion is complete. Above, where the upper extremities are held apart by the intervening ejaculatory ducts, they continue more or less distinct. The result is the single median structure of descriptive human anatomy.

The prostate consists of numerous short acino-tubular glands, held together and surrounded by a stroma of peculiar structure and arrangement.

The glands are developed from the mucous membrane lining the first portion of the urethra, as invaginations from the surface, or from outgrowths of epithelium lining the urogenital sinus (Griffiths). Now, the first portion of the urethra is developed from the stalk of the allantois, or in some measure, and so far as concerns the part that lies immediately around and below the orifice of the prostatic utricle, from the cloaca. It is therefore independent both of Müller's and the Wolffian

ducts; and the fact that the prostatic glands are developed from this, and are connected with it, might appear at first sight to negative the association of the prostate with the organs of generation, and to place it among those of micturition. The difficulty is, however, only an apparent one. The point of origin of the prostatic glands has simply been displaced, in the course of racial development, from the lining of the Wolffian ducts to that of the structure into which they open.

In this the prostatic glands do not stand alone. The origin of the ureters has been displaced in the same way. Originally they are prolonged from and open into the Wolffian ducts. Later they become shifted in position, and eventually they open into the enlargement of the allantoic stalk from which the bladder is formed (Schäfer). What is true of the one is equally true of the other; and the bilateral and symmetrical arrangement of the orifices of the prostatic ducts on each side of the veru montanum on the floor of the prostatic sinus may be regarded as a relic of their original separation.

The question of the existence of a median lobe, or, as Sir H. Thompson prefers to call it, of a median portion, depends upon the extent to which this displacement has occurred in each individual. So long as the glands are restricted to the prostatic sinus there is no median portion. In some instances a greater or smaller number are displaced farther towards the bladder, and then they not unfrequently occupy the middle line. Usually they remain upon the posterior wall of the urethra, and form a more or less conspicuous median lobe. Exceptionally they make their appearance upon the anterior wall as well.

The stroma of the prostate consists of muscular fibre-cells arranged concentrically around the alveoli, and of muscular and fibrous tissue holding these together. In the embryo it is structurally continuous with the tissue that invests and surrounds the vesiculæ seminales and the termination of the vasa deferentia. The stroma, as I have shown in the Hunterian Lectures on the Operative Treatment of Enlargement of the Prostate, is distinct from the wall of the urethra, and is developed, not from the allantois, but from what is known as the genital cord—a thickened mass of tissue that surrounds the Wolffian ducts as they course together towards the cloaca, behind the allantoic

stalk. Its purely sexual character is shown by the way in which it wastes after castration, and by the fact that in those animals in which the development of the generative organs varies according to the time of year, the change in the stroma is quite as striking as that in the glandular part or in the testes (Griffiths).

The urethra runs between the anterior margins of the two lobes of the prostate, the inferior extremities of which meet together behind it. In front of it is a variable amount of stroma, containing occasionally a few glands. The circular muscular coat of the bladder is continued down, around the urethra, unaltered, except that it is perforated by ducts of the prostate, &c., and that, because of the mechanical support lent it by the prostate, it is thinner and not so strong as it is above and below. The longitudinal coat of the bladder, arising in part from the pelvic fascia and the puboprostatic ligaments, passes on to the outer surface of the prostate, which may therefore be said to interpose itself for a very short distance between the two.

The function of the prostate bears this out. It is a purely sexual gland, having nothing to do with micturition, except in so far that, by surrounding the first portion of the urethra, it lends it a certain amount of support, and enables it to dispense with a thick muscular layer of its own. This is shown by the time of life at which its evolution is completed; by the fact that if the testes are removed in infancy it never develops, if in adult life it wastes and atrophies within a few weeks; by the way in which in many animals it varies in size according to the breeding season; and by the fact that in women, children, and eunuchs micturition is in nowise more difficult than it is in adult men.

Its chief function is to add certain constituents to the seminal fluid at the time of its discharge; or, more probably, from the extreme width and shortness of the ducts, and the peculiar arrangement of the stroma around them (Griffiths), to pour a secretion into the prostatic urethra immediately before the entrance of the fluid from the vesiculæ seminales and testes. According to Fürbringer, if the prostatic secretion is wanting, the semen fails in its characteristic odour; no Böttcher's crystals can be developed from it; and the spermatozoa, though living, are motionless. Fürbringer arrived at the conclusion that its function was to arouse and maintain the slumbering vitality of

the spermatozoa. He obtained the secretion of the testes, mixed with that of the vesiculæ seminales, from a patient suffering from atonic spermatorrhœa. The semen that escaped during micturition or defæcation was entirely deficient in the qualities above mentioned. That, on the other hand, which was discharged during sexual excitement was normal. The difference he attributes to the absence of the prostatic fluid in the former case.

The prostate in men over fifty years of age nearly always contains a number of small polyhedral bodies, with concentric markings upon them, occupying the alveoli of the glands. These are formed from the secretion that is not discharged, but remains behind, and in course of time becomes inspissated and hardened. The older they are and the larger they become, the greater the proportion of phosphate of lime they contain. The animal constituents are absorbed and the earthy ones left. According to Sir H. Thompson, the proportion of inorganic matter varies from 46 to 86 per cent. In one case under my care in which they were of unusual size, it amounted to as much as 92 per cent.

The intense congestion of the mucous membrane covering the veru montanum during sexual excitement closes the entrance to the bladder and prevents regurgitation of semen during emission. In this the muscular stroma of the prostate may assist; and as the action of the voluntary muscle that surrounds the apex of the gland and forms the sphincter of the bladder must be suspended at the moment in question, it may also help the passage onward of the fluid that is poured out into the urethra, until it is brought into the grasp of the muscles lower down. But there is no evidence that the prostate itself, apart from the levator prostatæ muscle, takes any active share in ejaculation over and beyond this.

According to Finger, the prostate acts as a sphincter for the vesiculæ seminales by virtue of a ring of smooth muscular fibre that can be traced along the ejaculatory ducts in their course through the prostate. I have not, however, been able to convince myself that these muscular fibres are additional structures, not present elsewhere upon the ducts; and Finger does not bring forward any reason why they should be considered to belong to the prostate, and not to the ejaculatory ducts themselves.

ARE THE EXTRINSIC MUSCLES OF THE AIR-BLADDER IN SOME SILUROIDÆ AND THE "ELASTIC SPRING" APPARATUS OF OTHERS SUBORDINATE TO THE VOLUNTARY PRODUCTION OF SOUNDS? WHAT IS, ACCORDING TO OUR PRESENT KNOWLEDGE, THE FUNCTION OF THE WEBERIAN OSSICLES? A CONTRIBUTION TO THE BIOLOGY OF FISHES.

By WILLIAM SÖRENSEN, Copenhagen.

(*Continued from page* 189.)

I TAKE the liberty here, as ten years ago, to point out that, by Moreau's statement of the manner in which the air-bladder of *Trigla hirundo* produces sounds, the reader may be led to suppose that Moreau attributes to the vibrations of the perforated internal transverse septum greater importance than is due to it, as far as I can judge; his words are apt to convey to the reader the impression that he thinks the fish owes to this diaphragm alone the production of sounds. In my opinion,[1] the air-bladder is capable of producing sound, but weaker ones it is true, even if the said diaphragm did not exist.

In *Sciæna aquila*, *Umbrina cirrhosa*, *Trigla lyra*, *Peristedion cataphractum*, and *Hippocampus brevirostris*, the air-bladder, according to Dufossé, produces sounds under the action of muscles with the fascia of which the air-bladder is intimately connected. While as regards the remaining fishes which he has examined, this author judges the air-bladder itself (with its gaseous contents) to produce the sound by the contraction of the extrinsic or intrinsic muscles, he is of opinion, with regard to the species here mentioned, that the air-bladder only serves to intensify the sound, which he considers to be produced by the vibration of the muscles while contracted; in other words, to be a muscular tone. Though I have not been fortunate enough to examine any living fish in which these conditions were

[1] As to this species, I have only examined it when dead. My opinion is not only based on my examination of living specimens of *Tr. gurnardus*, but on my whole knowledge of the air-bladders, which I have examined in living as well as in dead fishes.

present, I cannot subscribe to this opinion, but must consider the sound as being produced by vibrations of the air in the air-bladder and of the wall of the latter, when set in motion by the muscles with the fascia of which it is connected: firstly, because the sound, produced by the mere contraction of a muscle, is very faint in itself; and secondly, because, if his opinion were correct, it would be a mystery why sounds were produced by the contraction of some muscles and not of others, and that this is the case[1] has been proved by Dufossé (V*a*, p. 43): when he cut the nerve of the muscle in question on one side of the body the sound grew fainter, and quite ceased when the nerve on the other side was also divided. Further, Dufossé has found the height of the sound in *Peristedion cataphractum* and *Trigla lyra* to correspond with 517, nay, even with 870 vibrations in the course of a second; these very numbers appear to me too high by far to be reconciled with the sound being a muscular tone. And finally, it appears to me that the strength of the opinion of Dufossé is weakened by his own experiment (V*a*, p. 42, 43): when he extirpated the air-bladder of a *Trigla lyra* and replaced it by the foremost chamber of the air-bladder of a *Cyprinus carpio*, which chamber he then filled with air.

"Si j'ai opéré avec assez de promptitude et avec toutes les précautions que réclame cette expérience, le Poisson recommence à bruire, et les sons qu'il forme sont presque semblables à ceux qu'il émettait avant le commencement de la vivisection."

This experiment seems to me clearly to prove that the air-bladder (even if it be that of another fish) is rendered capable of emitting sounds when compressed by muscles capable of acting in a certain manner. It is here the place to add that, according to Dufossé, the musculi intracostales in question are extended between the os scapulare (Cuv.) and the 7th–10th vertebræ, and that they form two prominent masses of muscles, between which the air-bladder is imbedded.

Now, to return to the Siluroidæ, I have shown that the foremost strong, sometimes powerful, ray of the pectoral fins, and,

[1] This is still more confirmed, as far as I can see, when we consider the production of sounds (by means of the os præoperculare) in Cottus; but it would lead me too far here to explain this fact more fully.

in a manner, the strong ray of the dorsal fin, are sound-producing organs. This fact is explained in the following manner:—The animal has in its power to render these more or less powerful

FIG. 4.—*Doras maculatus*, Cuv. et Val., of a specimen measuring 50 cm. of length; natural size. The hinder part of the helmet (*C*) and the muscular crests of the interspinous bones (*Sb*², *Sb*³) are persected. Laid open to the view are δ, the left side of the roof-like keel of the second interspinous bone; *ar*, the articular cavity for the median part of the articular face of the strong ray.

weapons as it were immovably fixed by means of a mechanism, which, by the way in which it operates, bears the greatest resemblance to the brake of a wheel,—for instance, that of a railway carriage. In the first ray of the pectoral fins this brake consists in a crest-like arched process, springing from the upper

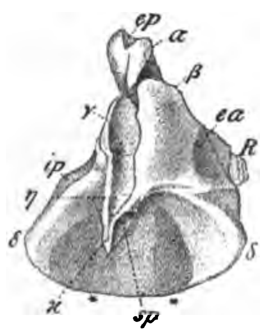


FIG. 5.—*Doras maculatus*, Cuv. et Val. The first ray of the right pectoral fin, seen from the base and a little obliquely from above; natural size. Of a specimen measuring 69 cm. of length.

side of the base of the ray, and passing forwards and backwards in an excavation of the "humerus" (Cuv.) during the movements of the ray, and pressed against the walls of the excavation when the ray is to be fixed.[1] In the dorsal fin this is effected by

[1] Professor Gegenbaur, in his well-known work "Schultergürtel der Wirbelthiere, Brustflosse der Fische" (*Untersuchungen zur vergleichenden Anatomie der Wirbelthiere*, Heft 2, Leipzig, 1865), among the Teleosteans, has made the study of the Siluroidæ his particular task. This work being generally considered as

means of the preceding "rudimentary" ray, which ray is wanting when the large ray is flexible all through, and accordingly no weapon. The posterior surface of this "rudimentary" ray is excavated, and may be pressed against a roof-like process

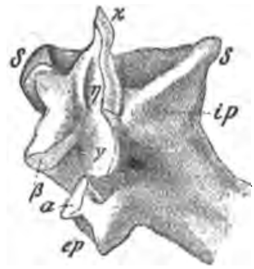


FIG. 6.—*Doras maculatus*, Cuv. et Val. The same object as in Fig. 5, seen obliquely from the base, from behind and from below.

(fig. 4) which springs from the interspinous bone.[1] Now, as a sound is produced when the brake of a railway carriage in motion is put in action, in the same manner here. When the pectoral fins are moved forwards or backwards, and when the dorsal fin is moved backwards—for the latter can never be fixed when moved forwards—a discordant sound is produced when the brake begins operating.[2]

one of the most important works on these subjects, I must point out that he is mistaken in mentioning (pp. 116–117 and 153–155) this process as part of the diarthrosis of the ray. Firstly, on functional grounds, it cannot be said to form part of the diarthrosis, as it does not serve to facilitate the movement, but to prevent it. Nor can it, from a morphological point of view, be called part of the diarthrosis: the rays of the pectoral fins do not in any fish articulate with the bone called by Cuvier humerus, and by Geoffroy Saint-Hilaire clavicula. On this point Cuvier et Valenciennes (XV., T. XIV. p. 318) were already well informed.

[1] Professor Haddon ("On the Stridulating Apparatus of *Callomystax gagata*," *Jour. of Anat. and Phys.*, T. XV., 1881, pp. 322–326) has arrived at the result that a sound is produced in *Callomystax gagata* when the channeled faces of the first and second interspinous bones are rubbed against other likewise channeled faces of the confluent spinous processes of the 4th and 5th vertebræ. When I referred to this result in my book (II*b*, p. 120) I expressed a doubt whether this suggestion was not based on imperfect observation. This doubt I now find still more confirmed. For though I do not know the anatomy of this fish, fig. 68 (Pl. XVI.) of the lately-published work of Professors Bridge and Haddon (I*b*) quite clearly shows not only the "rudimentary" ray, but also the well-known roof-like process behind it, on the interspinous bone.

[2] Starting from the Siluroidæ, I have pointed out similar conditions in a series of several Fishes:—At the dorsal fin in Balistes, Monacanthus, Acanthurus, Capros,

As, however, the large ray of the dorsal fin and the first ray of the pectoral fins in the great majority of the Siluroidæ are developed as a weapon, I was, with regard to this family, prevented from using one of the methods I generally employed to enlarge my knowledge of the air-bladder as a sound-producing organ,—that

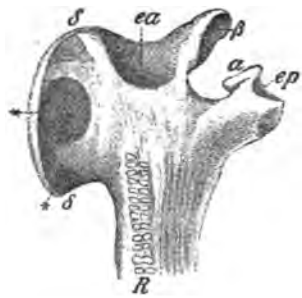


FIG. 7.—*Doras maculatus*, Cuv. et Val. The same object as in figs. 5 and 6, seen in front, somewhat obliquely.—In Figs. 5-7 the different parts, designed by letters, are: *R*, the foremost denticulated edge of the ray; δ, δ, the process, acting as a brake; *, *, the scouring faces of this process; γ, v, the vertical part of the diarthrosis; α, β, the two remaining parts of the diarthrosis, each on its process; *ea*, the place of insertion of the two muscles, leading forwards the ray; *ip*, the place of insertion of the muscle, leading backwards the ray; *ep*, the place of insertion of the muscle, which permits the ray to move backwards, but prevents it from moving forwards; *sp*, the place of insertion of the muscle, which permits the ray to move forwards, but prevents it from moving backwards. (This muscle, which does only exist in Doras, is a specialised portion of one of those muscles, which move forwards the ray.) κ, the process, carrying "*sp.*"

is, the examination of such fishes as were said, in the literature, to produce sounds. *Malapterurus electricus* being provided, according to Joh. Müller, with an "elastic spring" apparatus, it was not unlikely that the air-bladder was capable of producing sounds. And the first ray of the pectoral fins being quite flexible, while the dorsal is altogether wanting,—the only remainder is one interspinous bone,—most likely this fish, *if* it were able to produce sounds, would have to do so by means of the air-bladder. But though this fish, on account of its electric organ, has often been the object of examinations, I did not succeed in finding any indication as to its capability to produce

Triacanthus, Centriscus, Gasterosteus, and Anarrhicas; at the ventral fins in Triacanthus, Capros, and Gasterosteus; at the os hyomandibulare in Dactylopterus; at the os præoperculare in Cottus (II*b*, pp. 5–82, where the details are given).

sounds. I therefore asked my sister, Mrs Ida Leschly, who was then staying in Mansourah on the Nile, to procure a living specimen of this species, that she might learn whether it were able to produce sounds or no. Though the fishermen were not aware of the fact, she was fortunate enough to hear, and very distinctly, sounds repeatedly produced by one of the three specimens she got, and which had been deposited in a jar of water immediately after being captured. When the fish was

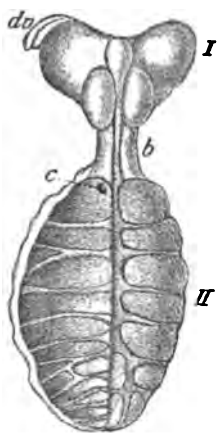


FIG. 8.—*Malapterurus electricus* L. The air-bladder seen from below. The second portion is opened along with the longitudinal septum; to the right the wall is moved a little aside, so as to show the low transverse septa. *b*, the constricted part between the anterior (I) and posterior (II) portions of the air-bladder; *c*, the hindmost opening of the right channel, uniting the anterior and the posterior portions; *dv*, one of the two circular plates at the fore-end of the air-bladder; nothing but the edge is visible, being a little removed from the air-bladder.

brought to her, it had recently been taken in the river; it was all alive, frisky, and unapproachable on account of the vigorous shocks which it imparted, in spite of its inconsiderable size. She described the sound as not unlike the hissing of a cat. This appeared somewhat strange to me; but, after I had dissected the fish, I could easily account for it by the long, narrow ducts through which the air has to pass from the anterior to the posterior chamber of the air-bladder. My sister was able to state that the sound was not accompanied by any gasping for air or any beating with the tail.

It is a matter of course that, on account of this statement, it was so much easier to me to consider the air-bladder as a sound-producing organ when the "elastic spring" apparatus does exist.

Starting from the suggestion that this apparatus does exist in all species of the genera Doras, Oxydoras, Rhinodoras,[1] Auchenipterus, Euanemus, Malapterurus, and Synodontis, and that the extrinsic muscles have the same function in all species of this family as in the two genera I had observed in living specimens, it may *now* be stated that the air-bladder serves to produce sounds in sixty-eight species[2] of this family, or in more than the tenth part of the species belonging to this family,—unquestionably, a result differing somewhat from that at which Bridge and Haddon have arrived; according to these authors (*Ib*, p. 270), "doubtful examples of the association of the air-bladder with phonation in a few Siluridæ and Cyprinidæ." But I may be allowed to add that there is sufficient reason to *presume* the air-bladder to be a sound-producing organ in more species than the

[1] Kner, R. ("Ueber einige Sexualunterschiede bei der Gattung Callichthys und die Schwimmblase bei Doras," in *Sitzungsberichte d. k. Akad. d. Wiss. Wien*, Vol. XI., 1855, pp. 138–146; and "Ichthyologische Beiträge," *ibid.*, Vol. XVII., 1855, pp. 92–162), has found this apparatus in 9 species of the genus Doras, in 7 species of the genus Oxydoras, and in 2 of the genus Rhinodoras. From his memoir it appears that he has found this apparatus in all the species examined.

[2] Günther (XVI., vol. v.) enumerates 13 species of the genus Doras (besides 3 species mentioned), 7 species of the genus Oxydoras, 3 species of the genus Rhinodoras, 9 species of the genus Auchenipterus, 1 Euanemus, 3 species of the genus Malapterurus, 12 species of the genus Synodontis. According to Bridge and Haddon (*Ib*), an "elastic spring" apparatus does also exist in 4 species of the genus Pangasius. Extrinsic muscles exist in *Centromochlus megalops*, *Trachelyopterus tæniatus*, and *Sorubim lima* (according to Kner, "Ichthyologische Beiträge II." in *Sitzungsberichte d. k. Akad. d. Wiss. in Wien*, vol. 26, 1857, pp. 373–448); *Platystoma fasciatum* (acc. to Joh. Müller); *Pl. sturio*, *Pl. Vaillantii*, and *Pl. platyrhynchus* (acc. to Kner); *Pl. tigrinum* (acc. to Bridge and Haddon); *Pl. Orbignyanum*? (acc. to me); *Pseudaroides clarias* (acc. to me); *Piramutina piramuta* (acc. to Bridge and Haddon); *Piratinga filamentosa* (acc. to Joh. Müller); *Pimelodus gracilis* (acc. to Kner); *P. ornatus* (acc. to Kner, Bridge and Haddon); *P. ranina* (acc. to Cuvier and Valenciennes); *P. maculatus* (acc. to Cuv. and Val., Bridge and Haddon). Bridge and Haddon (*Ib*, p. 246) having declared not to have found extrinsic muscles in any fish of this family except in the Pimelodina, we had perhaps better, at the present, doubt the existence of such muscles in *Rita pavimentata*, *Ælurichthys Gronovii*, and *Æl. marinus* (acc. to Cuv. and Val.); *Amiurus cauda-furcatus* (acc. to Kner); *Am. catus* and *Arius Milbertii* (acc. to Cuv. and Val.). In *Arius cœlatus* these authors state that they exist, but Bridge and Haddon deny their existence in this species.

above-mentioned. At anyrate, there is some reason to *presume* that the division of the air-bladder, effected either by external diverticula or by transverse septa, or in some other way, which by different authors is said to exist in several Siluroidæ, where extrinsic muscles or "elastic spring" apparatus are not present, may have some relation to the production of sounds. I here take the liberty to direct the attention of other naturalists to this subject.

I ought further to add, that in *Silurus glanis* it was impossible for me, at the present stage of the knowledge of the air-bladder as a sound-producing organ, to see that this organ had any function in this respect. And in *Clarias macracanthus* and *Plecostomus Villarsii* it does not appear possible to me that this organ could have that function.

As may be seen from what I have quoted above (pp. 122–124) from my observations during the vivisection of the mentioned animals, intricate or difficult physiological examinations are out of the question. On the contrary, the fishes that I have been vivisecting being animals of the length of 25 cm. up to 1 metre, and their air-bladder, as well as the muscles which cause the production of sounds, being organs of considerable size, the examinations are easy enough, provided that a sufficient material be at hand (but the Rio Paraguay is very rich in these fishes) for, of course, life is not long in being extinguished in fishes on shore and with opened bellies.

If it has not been sufficiently proved by what has already been said, I must direct the reader's attention to the fact that the extrinsic muscles of the air-bladder in Platystoma and Pseudaroides do not produce the effect attributed to them by Bridge and Haddon (*Ib*, p. 115, on *Platystoma tigrinum*): "As the contraction of these muscles must necessarily lead to the forcible compression of the anterior chamber of the bladder, . . . we shall in future mention them as the 'compressor muscles.'" They do not, by any means, compress the air-bladder: the immediate effect—which lasts only a moment—of their contraction consists in moving forwards the anterior part of the wall of the air-bladder. But I feel bound to add that the authors are not to be blamed for having drawn this conclusion

from the purely anatomical data, for they only followed Joh. Müller (VIII.).

With regard to the morphological interpretation of the muscles of the "elastic springs," the authors are of opinion (*Ib*, p. 230) that they are specialised portions of the dorso-lateral musculature. I cannot indorse this opinion. This may *perhaps* be the case in Synodontis, where these muscles have quite a different position [1] from that of the other genera; but in these genera they appear to me, according to their whole position, to be quite homologous with the extrinsic muscles of the air-bladder in the Pimelodina.

Bridge and Haddon have made a discovery which appears to me most interesting, viz., a pair of small muscles, which are said always to exist when "compressor" muscles are present. They "arise from the ex-occipitals, and are inserted into the anterior wall of the anterior chamber of the air-bladder." I have overlooked these muscles, most probably because, as I am led to presume by the figures of Bridge and Haddon, they are concealed by the pronephros; and, living in the wild forests of that country, I was only able to dissect the animals the very same day they were taken; the next day they were rotten, on account of the hot climate. What is the function of these muscles I cannot, therefore, say for certain; however, they serve, I suppose, to support the big extrinsic muscles. But what I firmly believe is, that they do not fulfil the function attributed to them by Bridge and Haddon, viz., that "of limiting the violent excursions of the tripodes [mallei] which might otherwise take place when the anterior chamber is forcibly compressed by the contraction of its compressor muscles."

I should think that whosoever has perused my "Observations on the producing of the sound" quoted above, even if he should judge the opinion set forth there about the *manner* in which the sounds are produced to be quite inaccurate, will agree with me that the production of sound is brought about by the said muscles, so that this opinion of mine is not "an ingenious theory," but a plain fact. And when Professors Bridge and Haddon are of opinion—and as to this opinion I quite agree with them—that the theories which they have propounded on the function of

[1] See my book (II*b*, p. 125, fig. 48), or Joh. Müller (VIIIc., Tab. III. fig. 4).

these muscles and the "elastic spring" mechanism are incompatible with my "theory," then their suggestions must be considered, for that very reason, as null and void.

And if they had known my paper, published in 1884, and that of Dufossé (V*b*), published in 1874, they might probably have been able to multiply, even to a considerable degree perhaps, the number of the Siluroidæ in which the air-bladder is a sound-producing organ. As for me, I can only say, according to the text and figures of the authors, that beyond what has hitherto been known, that is the case in *Pangasius Buchanani*, *P. djambal*, *P. macronema*, *P. juaro*; *Platystoma tigrinum* and *Piramutina piramuta*. For, though it is most probable that several others, besides those which I have mentioned here, might, if subjected to an anatomical examination with this aim in view, be recognised as being furnished with an air-bladder, serving as a sound-producing organ, I am not able, with no other basis than their examinations, to state it as a fact with regard to any more forms.

I would add that the part of the memoir of Professors Bridge and Haddon which deals with the function of the air-bladder and the Weberian ossicles, would have presented quite a different aspect if they had known my paper on sound-producing organs in fishes.[1] This part of their work would also have looked quite differently if they had thoroughly studied the physiological investigations made in modern times on the subject of the functions of the air-bladder.

More than 200 years ago, Borelli[2] (Lib. I. p. 332 *seq.*) set

[1] In a "Note on the Production of Sounds by the Air-bladder of Certain Siluroid Fishes," communicated to the Royal Society of London, April 26, 1894, and which appeared in the part of the *Proceedings* issued 24th July 1894, some weeks after this part of the manuscript was sent to the Editors of the *Journal*, Professors Bridge and Haddon "draw the attention of those interested in the subject to Dr. Sörensen's researches," and "express our regret at the injustice we have unintentionally done him." I cannot refrain from observing that I have not attracted the attention of the authors to this fact; the Note has been published against my wish; the two passages of my paper which the authors have translated in their note, are in mutual contradiction because of their having translated, in the passage on Doras, p. 89, the Danish word "utvivlsomt" by "very doubtful" instead of "without doubt." (See quotation from my paper in the October number of this *Journal*, p. 128, where these two words are printed in italics.)

[2] Borelli, *De motu animalium*, Romæ, 1680.

forth the hypothesis that, by compressing the air-bladder, the fishes lowered themselves in the water, and that, by distending it, they rose again, as if their body were the stiff bulk of a vessel incapable of changing direction in the same manner as other Vertebrata by bending their bodies. Though this hypothesis cannot be said ever to have been borne out, and in spite of the weighty arguments urged against it by Delaroche[1] (pp. 249–250) at the beginning of this century, this opinion has been prevalent until the last quarter of our century. No wonder, then, that Joh. Müller,[2] when he discovered the remarkable "elastic spring" apparatus in the mentioned genera of the Siluroidæ, set forth as his opinion that this mechanism served to help the fish to sink and rise in the water, according to the muscles being relaxed or contracted to a smaller or greater extent; nay, that more probably ("vielmehr") they served to give the fish an oblique direction, downwards, when the muscles of the springs were relaxed, upwards when they were contracted (VIII*c*).

Delaroche, in opposition to the hypothesis of Borelli, put forth another, which for certain reasons I take the liberty to quote. He says as follows (XIV. p. 261):—

> "Il résulte de ce que je viens de dire, que la vessie n'a pas d'autre usage bien constaté que celui de mettre la pesanteur spécifique des poissons en équilibre avec celle du milieu ambiant."

If he had confined himself to these words, it would have been so much the better, for that is correct, and even he was not able to support this statement with as weighty arguments as did Moreau about seventy years later,—the reasons he gave were of great weight. But less fortunately he adds (*ibid.*, pp. 262–264):—

> "Les muscles propres qui sont fixés à ses parois dans un grand nombre d'espèces, ont probablement pour usage de comprimer plus ou moins fortement le gaz qu'elle renferme, non comme le supposent ceux qui ont adopté l'hypothèse de Borelli pour changer la pesanteur spécifique du poisson, mais au contraire pour le maintenir toujours au même

[1] XIV: Delaroche, F., "Observations sur la vessie aërienne des Poissons" (*Annales du Mus. d'Hist. Nat.*, T. XIV., Paris, 1809, pp. 184–217; pp. 245–289).

[2] VIII*a*: Müller, Joh., "Beobachtungen über die Schwimmblase der Fische, mit Bezug auf einige neue Fischgattungen (*Archiv f. Anat. u. Physiol.*, Berlin, 1842, pp. 307–329).—VIII*b*: Müller, Joh., The same matter (*Monatsber. d. k. Akad. d. Wiss.*, Berlin, 1842, p. 202).

point. . . . Il faut donc, pour que leur pesanteur spécifique ne varie pas, qu'il y ait une cause toujours agissante qui empêche cette condensation et cette dilatation. Telle paroît être la fonction des muscles propres de la vessie. . . . On peut raisonnablement supposer que les muscles abdominaux remplacent ces muscles propres chez les poissons qui en sont privés." Though this is certainly incorrect, yet it appears to me an improvement of the Borellian hypothesis.

As I am here going to mention several[1] of the theories put forth in the course of time touching the functions of the air-bladder, I feel bound not to pass the suggestions of Cuvier and Valenciennes. With regard to the form and structure of the air-bladder in the Sciænoidei, these authors say[2] (T. V., 1836, p. 3):—

"... et bien que ces vessies natatoires ne paraissent pas avoir de communication avec l'extérieur, comme presque toutes les sciénoïdes font entendre des bruits, des grognements, encore plus marqués que ceux des trigles, il est difficile de croire que la disposition de ces organes n'ait pas quelque rapport avec cette propriété." And as to *Batrachus grunniens* (*ibid.*, T. XII., 1837, p. 471):—"Cet appareil musculaire de la vessie doit contribuer, comme dans les autres poissons grondeurs, au bruit que les batrachoïdes font entendre." Nay, Valenciennes afterwards, when mentioning the sounds produced by the Siluroid genus Synodontis, feels so sure about this theory, that, with much more weight than he was entitled to, he declared (*ibid.*, T. XV. p. 251):— "Tous ceux, d'ailleurs, qui connaissent l'histoire naturelle des poissons, savent que les sons que ces animaux font entendre sont dus au mouvement qu'ils peuvent donner à l'air de leur vessie natatoire, en exerçant sur cet organe une compression plus ou moins forte quand il est pourvu de muscles constricteurs . . ."

This was, maybe—in the real meaning of the words—an "ingenious theory," but nothing more. For, with the exception of Aristotle, whose words[3] I have placed at the head of the first

[1] Such theories as must be said to have been mere vagaries or not to have been generally adopted, I entirely pass.

[2] XV: Cuvier, G. et Valenciennes, A.: *Histoire naturelle des Poissons*, Paris, 1828–45.

[3] I may perhaps be allowed, though no linguist, to point out that the philologists have, quite naturally, misunderstood this sentence. At anyrate, all the interpreters (4–5) of Aristotle whom I know of have understood it as if the meaning were: "others (of these Fishes) produce the sound by means of their bowels in the vicinity of their stomach. Each of these bowels contains air." But *ἕκαστον* does not refer to *τοῖς ἐντὸς περὶ τὴν κοιλίαν* but to *πάντα δὲ ταῦτα* (o: all these Fishes).

And now, this sentence being no longer obscure, it is clear that it is to be translated thus: "But all these (Fishes) produce something like a voice, some

section of this paper, which are perhaps—and most likely too—based on real investigations, all theories touching the manner in which fishes are producing sounds, propounded before Holbrook, Dufossé, and Moreau, are mere theories, or, properly speaking, mere hypotheses.

In 1876 Moreau, in his work (VI.), which made an epoch in this point of natural history, leaning upon physiological experiments, proved that the air-bladder—to express myself in a few words—serves to equilibrate the body of the fish with the water at a certain level after the lapse of some time, the capillaries of its walls either absorbing air from the air-bladder or secerning air into it. And with regard to the only fish among those furnished with muscles in the air-bladder which he had examined, viz., Trigla, he proved, as did also Dufossé, that they served to make the air-bladder sound.

A thorough examination of the function attributed by Bridge and Haddon to the elastic spring mechanism (I*b*, pp. 298–300), as to the extrinsic muscles (I*b*, pp. 300–301), on which subject I have above quoted the principal remarks of these authors, will show that they are of opinion that these organs serve, in a slightly varying manner, as a "pressure adjustment," *i.e.*, they adjust the volume of the air-bladder to the pressure of water to which the fish is exposed, and perhaps also by expelling some of the air through the pneumatic duct. In other words, apart from this last phrase, their theory is the very same as that which Delaroche had put forth eighty-four years before, not, it is true, as to the Siluroidæ, but as to fishes in general. Though Bridge and Haddon have presumably [1] known the theory of Delaroche which I have referred to, they have not been aware that their theory is quite identical with that of Delaroche. But the long interval makes a great difference: when the hypothesis was put forth by Delaroche, no facts were known with which it was incompatible, and it was in fact an advance upon the then prevalent theory of Borelli. But in 1893, when it was repeated by

by rubbing the gill-arches [one against the other], these organs being furnished with teeth [literally thorns]; others by means of the air-bladder [literally: the bowels around the cavity]. Each of these (Fishes) contains air, by the rubbing and moving of which the sound is produced."

[1] The theory of Delaroche is amply reported by Moreau.

Bridge and Haddon, it has been crushed, as may be seen, several years ago, not only by my examinations (unknown to them) of the very Siluroidæ, but also by authors with whom they have been acquainted, viz., Moreau and Charbonnel-Salle,[1] which French authors they obviously have read. How they have been able to bring this theory of theirs to accord with the experimental investigations made about the air-bladder by Moreau and Charbonnel-Salle is a mystery to me. The latter having examined both physoclyst (Perca) and physostome fishes (Esox and several species of Cyprinoidei), says as follows:—

"Quand le Poisson nage tranquillement, sans provocation extérieure, le tracé [by means of an apparatus analogous with the sphygmoscope by Chauveau et Marey] de la vessie est identique et parallèle à celui de l'ampoule hydrostatique; aucune inflexion brusque ne signale une contraction de muscles [the air-bladder of these fishes has neither extrinsic nor intrinsic muscles] agissant sur la vessie, soit pour la comprimer (hypothèse de Borelli), soit pour la dilater (Geoffroy Saint-Hilaire), *soit enfin pour rétablir après chaque déplacement le poids spécifique modifié par la pression variable de l'eau* (*Delaroche*). La sensibilité de l'appareil permet d'affirmer que, dans ces conditions, des actes musculaires, même très faibles, ne passeraient pas inaperçus. Lorsque, au contraire, par des foulées énergiques de la nageoire caudale, le Poisson fuit avec vitesse, le parallélisme général des deux courbes est conservé, mais un élément se surajoute au tracé de la vessie natatoire: de véritables secousses des muscles latéraux hérissent le tracé et témoignent d'une brusque augmentation de la tension intérieure, tension qui retombe au zéro, au moment où la nageoire caudale, après s'être incurvée à droite, se recourbe à gauche en repassant par l'axe du corps. Il importe de remarquer que toute augmentation notable de tension est liée à l'incurvation du tronc; en dehors de cette condition, des secousses musculaires ont une action très faible sur la vessie. Or cette incurvation est exceptionelle dans la locomotion ordinaire du Poisson. *En outre, la brève diminution de volume ainsi produite a lieu aussi bien quand l'animal fait effort pour monter que lorsqu'il tend vers la profondeur.* Ce fait suffirait à prouver que l'augmentation de poids spécifique résultant de cette contraction ne joue aucun rôle dans la locomotion; car en admettant qu'elle favorise la descente, il faudrait admettre qu'elle entrave l'ascension. .—. . chez des poissons de 80 gr à 100 gr, l'augmentation du poids spécifique n'atteint, dans aucun cas, 0 gr, 50 et que cette force minime est appliquée au centre de gravité de l'animal pendant 5 à 7 centièmes de seconde, durée moyenne de la période de raccourcissement de la fibre musculaire. . . . En résumé, la vessie natatoire peut être comprimée par les muscles du tronc au

[1] Charbonnel-Salle: "Sur les fonctions hydrostatiques de la vessie natatoire" (*Compt. rend. d. l'Acad. d. Sci.*, T. CIV., Paris, 1887, pp. 1330–33).

même titre que les autres organes contenus dans la cavité abdominale. *Les changements de volume qu'elle subit, n'ont aucune signification fonctionelle*, ils n'aident nullement le Poisson dans ses changements de niveau ou dans ses changements de direction. Les deux théories classiques résumées ci-dessus doivent être définitivement abandonnées."

It is well worth noticing what Professors Bridge and Haddon consider to be the result of the physiological investigations of the two French authors. They say (*Ib*, p. 279): "From the conclusions established by Moreau and Charbonnel-Salle, it becomes obvious that the varying degrees of tension of the gaseous contents of the air-bladder due to variations in the height of the superincumbent column of water, constitute an important factor in the physiology of locomotion in Fishes."[1] Moreau, in the first page of his memoir, says: "Mais l'expérience II. . . . nous oblige de reconnaître que le rôle de la vessie natatoire admis pour la locomotion est imaginaire." And in another place[2] he says: "La vessie natatoire n'est point un organe de locomotion, mais elle est un organe d'équilibration." And (VI. p. 53) he says: "Delaroche accepte une manière de voir que les faits ne justifient pas." And Charbonnel-Salle distinctly declares that his experiments disprove the theory of Delaroche. Nay, to show whether Professors Bridge and Haddon have well understood the result to which Moreau and Charbonnel-Salle have been led by their experiments on the air-bladder as a hydrostatic apparatus, I confine myself to quote in addition the following passage of these authors, in a footnote on the page (*Ib*, p. 278) where they refer to the results of the above-mentioned French physiologists: "A Fish in equipoise in the water resembles the philosophical toy known as the 'Carthusian Diver,' and the slightest exertion of its fins will readily cause motion in the vertical direction," along with some words of Professor Charbonnel-Salle in another paper,[3] where, on the first page (p. 305), he mentions how the naturalists interpreted a Fish according to the ancient theories, he uses the following terms: "Il serait un ludion[4] portant en lui-même la cause active de ses déplacements," and (*ibid.*, p. 319) he says: "Ce résultat constant des expériences paraîtra peut-être suffisant pour juger la théorie du Poisson-ludion . . ."

[1] When these authors continue, "and hence, in the absence of any other tenable hypothesis as to its function, there is a strong *a priori* probability that the object of the Weberian mechanism is to acquaint the Fish with the varying degrees of tension to which the air-bladder may be subjected," here already I must declare this conclusion to be quite invalid, starting as it does from erroneous premises.

[2] Moreau, F. A., *Mémoires de Physiologie*, Paris, 1877, p. 179.

[3] Charbonnel-Salle, L.: "Recherches expérimentales sur les fonctions hydrostatiques de la vessie natatoire" (*Annal. d. sci. nat.*, 7 sér. T. II. Paris, 1887, pp. 305–331).

[4] The great dictionary of Littré: "Ludion, Terme de physique. Petite figure qui flotte dans une bouteille de verre pleine d'eau, et qui est construite de manière qu'on peut, à volonté, sans y toucher, la faire monter ou descendre par l'effet de la pression de l'air."

Though Moreau and Charbonnel-Salle are of opinion that they have crushed the Carthusian-Diver Fish, according to Bridge and Haddon, however, he is still diving.

I confess that I can only agree with three of the physiological views suggested by Professors Bridge and Haddon: firstly, that the experiments of Professor Jobert tending to bear out that Erythrinus respires atmospheric air in the air-bladder are not decisive[1]; secondly, that the theory of Sagemehl on the function of the Weberian ossicles is untenable; thirdly, that the sound produced by Clarias does not arise from the expulsion of air from the air-bladder. On this fish I have written eleven years ago[2] (p. 406):

> "It emits two kinds of sounds, of which one, produced simultaneously with a movement of the pectoral fins, was discordant . . . while the other sound was dull but distinct, and not unlike an eructation. The latter of these sounds has been observed several times as well in as out of water, the Fish at the same time opening its mouth without moving the pectoral fins." And I can add that the sounds which this Fish emits *under water when disturbed* are caused by the movements of the pectoral fins.

I said above that the curious air-bladders represented in the "Introduction" of Dr. Günther (with the exception of one) are those of different genera belonging to the *Sciænoidei*, in which family the air-bladder is well known to be a sound-producing organ. This, however, is not the impression derived from the perusal of Dr. Günther's book. The statement made about the manner in which fishes of this family produce sounds runs as follows (XIII. pp. 427–428):—"To this fish, (*P.*[*ogonias*] *chromis*) more especially is given the name of 'Drum,' from the extraordinary sounds which are produced by it and other allied Sciænoids. These sounds are better expressed by the word drumming than by any other, and are frequently noticed by persons in vessels lying at anchor on the coasts of the United States, where those fishes abound. It is still a matter of uncertainty by what means the 'Drum' produces the sounds. Some naturalists believe that it

[1] The reasons why I could not adopt the suggestion of this author, *i.e.* that the air-bladder is an organ of respiration, I have stated in my book, (II*b*, pp. 187–190).

[2] *Naturhistorisk Tidsskrift*, 3 R. Bd. xiii., Kjöbenhavn, 1883.

is caused by the clapping together of the pharyngeal teeth,[1] which are very large molar teeth. However, if it be true that the sounds are accompanied by a tremulous motion of the vessel, it seems more probable that they are produced by the fishes beating their tails against the bottom of the vessel in order to get rid of the parasites with which that part of their body is infested."

I take the liberty here to quote, in a somewhat different order, what I wrote ten years ago, where I had gathered all the elucidations published until 1884.[2] In doing so, I am able to show the reader, I suppose, that it is not a rarity whatever that Fishes produce sounds by means of the air-bladder.

With the exception of the Siluroidæ, the Triglidæ, and the Pristipomatidæ, none of the great families of fishes count so many species known as sound-producing. And the air-bladder in these fishes appears in the most varied and at the same time in the most complicated forms, now furnished with, now devoid of muscles, its cœcal diverticula extending into the musculature of the body and the tail, conditions which, by way of induction, led Cuvier and Valenciennes—at a time when there did not exist one investigation as to the mode in which sounds were produced in fishes—to the conclusion quoted above, that the air-bladder—and more particularly in this family—had something to do with the production of sounds. The following species are known to be sound-producing:—*Umbrina cirrhosa*, L.; *Sciæna aquila*, Lac.; *Sc. adusta*, Ag. (according to Ihering[3]); *Otolithus regalis*, Bl. (*Labrus squeteague*, Mitchill,[4] p. 398); and *Pogonias chromis*, L. (*Sciæna fusca*, Mitch., *l.c.*, p. 411). The fact is less certain with regard to *Pogonias fasciatus*, Lac. (*Labrus grunniens*, Mitch., *l.c.*, p. 405); *Corvina ronchus*, Cuv. et Val. (T. V., p. 107);

[1] That several Fishes of this family are able to produce sounds by gnashing their teeth is quite probable: nearly all Fishes may do the like. I have seen a *Gadus morrhua* in its agony gnashing its pharyngeal teeth, though they do not appear to be adapted for this purpose. But at anyrate this is a matter quite apart from the drumming sounds for which the Sciænoidei are so renowned.

[2] Since 1884 I have not followed the literature on this subject. The elucidations of Ihering, however, are of more recent date.

[3] Ihering, H. v., "Die Lagoa Dos Patos" (*Deutsche Geographische Blätter*, T. VIII. fasc. 2, p. 185).

[4] Mitchill, S. L., "On the Fishes of New York" (*Trans. o. t. lit. a. phil. soc. New York*, T. I., 1815, pp. 355-492).

Umbrina ronchus, Val.,[1] and *Umbrina Canariensis*, Val. (*ibid.*, p. 24); *Sciæna ocellata*, L. (*Sc. imberbis*, Mitch., *l.c.*, p. 411); *Larimus dentex*, Cuv. et Val. (T. V., p. 139); and *Micropogon undulatus*, L. (Cuv. et Val., T. V., p. 217 and p. 221; *Bodianus costatus*, Mitch., *l.c.*, p. 417).

Of all these Fishes I have only succeeded in examining (a dead specimen of)—

Micropogon undulatus.—The form of the air-bladder needs no other description than that given in the figure 9. On the middle[2] a pair of slender, round, hollow horns project, which

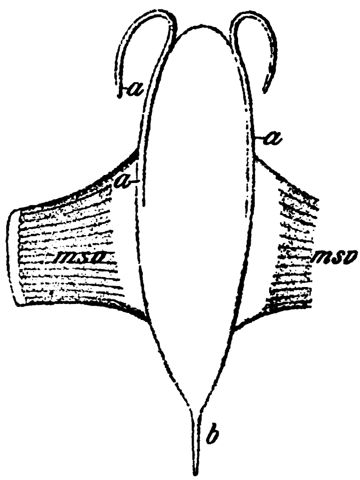


FIG. 9.—*Micropogon undulatus*, Linn. The air-bladder seen from below; natural size. (To the left the muscles are only partially shown.) *a,a,a*, the lateral horns of the air-bladder; *b*, the hinder point of the air-bladder; *msv*, the muscles, which must make the air-bladder act as a sound-producing organ.

extend forwards along the lateral wall of the air-bladder, at whose fore-end their final parts again turn backwards. The outer membrane is fibrous, stiff, of a silvery lustre; the inner one is pellucid, the "red corpus," formed like a horse-shoe, placed at the ventral side. On the dorsal side, the air-bladder is intimately attached to the vertebral column.

Musculature.—Below, on the ventral-lateral wall of the body,

[1] Valenciennes, in Webb et Berthelot, *Histoire naturelle des Iles Canariens*, T. II., pt. 2 (p. 24).

[2] Much farther behind in the specimen examined by Cuvier et Valenciennes (T. V., pl. 138).

near the lower end of this wall and that of the ribs, issue a pair of broad aponeuroses which ascend obliquely, inclosing the air-bladder, with which it is interwoven on the dorsal side a little before the base of the horns. The hindmost part of these aponeuroses is provided with a layer of muscles,[1] whose fibres turn obliquely upwards and forwards. The muscles, as well as the aponeuroses, have their greatest length (vertically) near their posterior end, and gradually grow shorter in front.

According to its structure, the air-bladder of this fish must be a sound-producing organ. Most probably the contraction of the muscles will, for a moment, compress the air-bladder and strain its dorsal wall, each of which operations must separately be able to bring the air-bladder to produce sound.

In *Otolithus regalis*, Bl. (Cuv. et Val., T. V., Pl. 138), *O. Cayennensis*, Lac. (*O. toe-roe*, Cuv. et Val., *ibid.*, Pl. 138), *O. guatucupa*, Cuv. et Val., *Ancylodon jaculidens*, Cuv. et Val., and *A. parvipinnis*, Cuv. et Val., the air-bladder has a similar form, according to Cuvier et Valenciennes, but the horns are considerably wider. These authors do not, however, mention whether it is provided with muscles or no.[2]

According to the description of the same authors (T. V., p. 200, Pl.[3] 139) *Pogonias chromis*, L., has in its air-bladder a sound-producing organ, no doubt the most powerful to be found in any fish (perhaps with the exceptions of Ganoids and "Dipnoi"). It is oval, broad behind, narrower in front, where laterally it expands into great wide cavities, which are in their turn lobed and incised. Its outer membrane is "gélatineuse et fibreuse," and is nearly half an inch thick (in a specimen of

[1] When I had only been able to examine dead specimens of a species, I have always made sure, by means of the microscope, that what I called muscles were really so.

[2] *L.c.*, p. 200, they say: "J'ai déjà fait remarquer que la plupart des Sciénoïdes les plus remarquables par cette faculté [to produce sounds] ont de grandes vessies natatoires, très-épaisses, munies de muscles très-forts." The presence of muscles, however, is only mentioned in Pogonias and Micropogon. Generally it is not noted whether the ends of the diverticula of the air-bladder extend into the lateral musculature of the body. Here is a wide field open to anatomical investigations.

[3] The figure in question is copied in the "Introduction" of Dr. Günther.

[4] Bridge and Haddon (*Ib*, pp. 273–274): ". . . it may be objected that in many Siluridæ the walls of that organ are too thick to admit of their vibrating synchronously with rapidly recurring sound waves."

three feet and a half in length). The hinder half, which is not furnished with appendages, is on either side covered with a very thick layer of muscles with transverse fibres; besides, the extremities of the ramifications of the lateral cavities partly penetrate between the ribs into the lateral muscles of the body. The "drum" is said to attain to a weight of a hundred pounds, and the tones which it produces seem to be of an enormous strength.[1] On this fish, Holbrook[2] has made the following observations:—"Frequent examinations of the structure and arrangement of the air-bladder, as well as observations on the living animal just taken from the water, when the sound is at intervals still continued, have satisfied me that it is made in the air-bladder itself; that the vibrations are produced by the air being forced by strong muscular contractions through a large opening, from one large cavity, that of the air-bladder, to another, that of the cavity of the lateral horn; and if the hands are placed on the sides of the animal, vibrations will be felt in the lateral horn, corresponding with each sound." This passage, then, is, as far as I know, the first statement in modern times of observations of the fact that the air-bladder is capable of acting as a sound-producing organ. Though the investigation itself has evidently been rather superficial, the correctness of the main fact is open to no doubt, when we bear in mind that this statement, the first in modern times, no longer stands alone But I very much doubt the correctness of the opinion of Holbrook as to the *manner* in which the sounds are produced. With a view to what I am going to state further on as to the importance of the production of sounds in the Siluroidæ, I take the liberty to quote the following passage from the same author: —"At this time [April] . . . begins its drumming noise; this season [the spawning-season] passed, the sound is no longer heard, and the fish is then rarely taken." The elucidations given by

[1] *Vide* Cuvier and Valenciennes, T. V., p. 198.

[2] Holbrook, J. E., *Ichthyology of South Carolina*, T. I., 1860, p. 118. This work is faunistic; of anatomical details it does not contain many, and the statement quoted above is the only piece of physiological information, as far as I know. It therefore appears to me that it would have been more natural if it were I who was unacquainted with this work of Holbrook, as I am by no means a systematical ichthyologist, and do not read English with any greater facility than I do the other languages of Gothic and Latin root.

Ihering (*loc. cit.*) on the habits of this fish also afford some interest: they "sollen nie vormittags, sondern von Mittag bis in die Nacht herein 'trommeln,' weshalb denn auch nur nachmittags und abends ihnen nachgestellt wird."

In *Pogonias fasciatus*, Lac., the air-bladder appears to be of the same structure. It would be most desirable if the air-bladder in one of these species were submitted to a renewed examination, which, even if it were merely anatomical, would undoubtedly bring to light interesting facts.

Sciæna aquila, Lac. In this fish whose musical performances probably have given rise to the Homeric fable of the song of the Sirens, the structure of the air-bladder is, according to Dufossé (V*b*, p. 5–22), briefly this: It is large (one-third of the total length of the fish), shaped like a long bag, and pointed behind; on either side it is furnished with 34–42 short ramified diverticula, among which the 6th–10th are the biggest. A great number of them, especially the larger ones, are intimately connected with the "aponeuroses" of the nearest among the lateral muscles of the body,—nay, the very largest penetrate through these muscles, even to an extent of 4 cm. Besides, the air-bladder is fused ("se soude") with the centra of the foremost vertebræ, and intimately attached to some of the processus transversi of the succeeding vertebræ and to the foremost ribs by means of very strong "aponeuroses"; and on its dorsal side it is intimately connected with the aponeuroses in the roof of the abdominal cavity. The wall is very thick;[1] the outer membrane fibrous and very compact; the inner membrane, which is thicker than is generally the case, forms a horizontal septum with a large oval aperture towards the fore-end, and in large specimens it extends above the orifice of the diverticula, so that the compartments of these diverticula are separated from the main compartments of the air-bladder. When solitary, the fishes of this species, according to Dufossé, but rarely emit sounds; and if so, these sounds are faint, dull, and of short duration; but when in flocks, and, above all, in shoals during the spawning season, they incessantly emit tones of such a power and duration, that all

[1] 7 mm.—1 cm. There is no indication as to the length of the specimens examined. The species attains to a length of 2 metres, and to a weight of 25–30 kilos.

their strength would seem to be quite exhausted by these exertions. The sound is so intense that specimens—large ones, I suppose—keeping at a distance of 18 metres under the surface of the water, are distinctly to be heard by a listener whose ear is 2 metres above the water. Previous authors—Bonaparte, Duhamel—state them to be still audible at a distance of 20 fathoms. By means of vivisections Dufossé has proved that tones can be produced by the activity of most of the muscles,[1] which, coated with "aponeuroses," are in immediate contact with the diverticula of the air-bladder, but that the most frequent and most intense tones are produced by the activity of those muscles, which, "completely naked," are placed around the long branches of the largest diverticula. The tones may be of different pitch, in perfect accordance with their being formed in different places (and under the influence of different muscles).

To judge from the structure of the air-bladder as represented by Cuvier and Valenciennes it must also be considered a sound-producing organ in the following Sciænoidei: *Sciæna ocellata*, L., where the diverticula penetrate between the ribs; *Sc. diacanthus*, Lac. (*Corvina catalea*, Cuv. et Val.), with 20 pair of diverticula, of which 18 are ramified in a high degree (T. V., Pl. 139); *Corvina coitor*, Buch., with 10 pair of diverticula, of which 9 are ramified; *C. Belengerii*, Cuv. et Val., where the air-bladder is, moreover, constricted near the fore-end; *C. lobata*, Cuv. et Val. (*ibid.*, Pl. 139), where it does not differ from that of the preceding species, but is very wide before the constricted place. It is less obvious in *Sciæna obliqua*, Mitch. (*Leiostomus humeralis*, Cuv. et Val.), where, as in *Sc. xanthurus*, Lac., it is very much like that of *Otolithus regalis; Corvina nigrita*, Cuv. et Val. (*ibid.*, Pl. 138), where from the fore-end issue two long horns, divided into several branches; *C. acoupa*, Cuv. et Val., whose horns are wider, but only bi-branchiate; *C. furcræa*, Lac., where the structure is the same; and *C. biloba*, Cuv. et Val., *C. axillaris*, Cuv. et Val., and *Nebris microps*, Cuv., with a pair of long unramified horns.—(In *Corvina*

[1] Dufossé points out that these muscles are of a more intensely red colour than the other parts of the lateral musculature of the body. In the Siluroidæ, Characini, and Trigla, which I have examined when alive, the muscles which make the air-bladder able to act as a sound-producing organ are also more intensely red than the rest of the muscles.

ronchus, Cuv. et Val., and *C. Senegalla*, Cuv. et Val., the air-bladder is like that of *C. nigra*, L., without any outer division or appendage whatever.)—In *Collichthys pama* (*ibid.*, Pl. 138) the form of the air-bladder is essentially as in Micropogon, but the horns are divided in front into several rather short branches. In *C. lucida*, Rich., it appears in one of the most remarkable forms to be met with; but, apart from this feature and from its stiff thick wall, nothing in the detailed description of it given by Günther[1] (T. II., p. 312) goes to prove its being an organ of sounds. The same must be said about the description by the same author (*ibid.*, p. 317) of the air-bladder of *Lonchurus depressus*, Bl.; "a process arising from the third vertebra," which process is connected with the air-bladder, is, however, mentioned in such a manner that we are led to suppose the existence of an ossification of the wall of the air-bladder. A renewed examination of this organ in these two species would therefore be most desirable.

Umbrina cirrhosa, L.—As to the relative size of the fusiform air-bladder, the manner in which it is attached to the skeleton and to the aponeuroses of the abdominal cavity, and as to the thickness of its wall, this species is, according to Dufossé (V*b*, p. 22–28), quite analogous to *Sciæna aquila;* but instead of the ramified diverticula, it presents only three pair of lateral bulgings, bipartite by a transverse fold, and connected with (". . . rapport de contiguïté . . .") the parts of the deepest (innermost) layers of the lateral muscles of the body, which fill up the intervals between the 3rd–5th ribs. Inside it is found, as in *Sciæna aquila*, a thin horizontal septum with a large, oblong hole on the middle. When the fish is out of the water, the sound can only be heard, at most, at a distance of 2 metres and a half, and is produced (at the greater part at least) by the activity of the said muscle portions, which are in contact with the air-bladder. Dufossé also relates the interesting circumstance that in young not yet pubescent specimens of a length of 2–3 dcm. (the fish attains a length of more than 2 feet), he observed the same vibratory movements ("frémissements") of the muscles, which in grown-up specimens produce sounds, but which had now no such effect. The vibratory movement was

[1] XVI: Günther, A., *Catalogue of the Fishes in the British Museum, London*, 1859–70.

easily felt at the surface of the body, but nearly imperceptible on the inside of the abdominal wall. On this occasion Dufossé makes the following remarks :—

"La répartition de l'intensité de ces mouvements explique pourquoi ils ne seraient pas bruyants, lors même que la vessie aurait acquis un degré de développement plus avancé que celui auquel elle est parvenue à l'âge des individus dont il est ici question. Toujours est = il que la multiplicité de ces mouvements de frémissement démontre l'aptitude que possèdent les fibres musculaires de ces animaux à engendrer des mouvements de cette espèce, aptitude qui s'étend alors à un grand nombre de muscles, et qui, par cela même, est un peu confuse chez les jeunes sujets, mais qui se concentrera plus tard dans les muscles de la couche profonde des grands latéraux, à l'âge où l'appareil de renforcement [the air-bladder], étant suffisament dévéloppé, sera convenablement disposé pour recevoir ces petits mouvements et pour leur donner la force nécessaire à ébranler le milieu ambiant."

But this suggestion, based as it is on the supposition that the sound arises from the vibration of the muscles themselves, is untenable. The difference must be owing to another cause, whether it be that the air-bladder is not connected with the abdominal wall in the same manner as at a later stage, or of some other reason. To a zoologist, residing on the shores of the Mediterranean, it would be an interesting task to study this problem.

It has been established already, in 1864, by investigations of Moreau,[1] and afterwards by those of Dufossé (published in 1874), who has examined no less than eight species of the genus Trigla, that the sounds emitted by these animals are produced when the walls of the air-bladder and its gaseous contents are thrown into vibrations. But though these examinations have been carried on with living animals, and though the two French authors agree on the main points,[2] yet the learned ichthyologist, Dr. Günther, tells us, in 1880 (XIII., p. 479) :—"The grunting noise made by Gurnards when taken out of water [as well as in the water] is caused by the escape of gas from the air-bladder through the open pneumatic duct." Unfortunately there exists no pneumatic duct at all[3] in these fishes. From whom, then,

[1] Moreau, A.: "Sur le voix des Poissons" (*Compt. rend. d. l'Acad. d. sci.*, T. LIX., Paris, 1864, pp. 436–37). Also in VI., p. 67.

[2] As, by the way, they do with my examinations of living specimens of *Tr. gurnardus*.

[3] *Trigla hirundo* certainly is, from a morphological point of view, furnished with a pneumatic duct, but this "duct" is a perfectly solid string.

does this error arise? From Sir Richard Owen, I think, who says[1] as follows:—"In a few genera (Trigla, Pogonias) the air-bladder and its duct are subservient to the production of sounds." But though it may be understood how this eminent anatomist could forget that this genus belongs to the physoclyst fishes, it is indeed a little strange that the great systematic Ichthyologist, Dr. Günther, could commit the same error. And whence, then, arises the error of Sir Richard Owen? I cannot with certainty answer this question, and I do not think it sufficiently important to trace it in literature. But as far as I have been able to judge, this error arises from misinterpretations, at second hand, of the remarks of Cuvier and Valenciennes, quoted above.

I have quoted the statements of Dr. Günther, in order to show justice to Professors Bridge and Haddon. I cannot fail to see that, so generally consulted as is the "Introduction" of Dr. Günther in England, in the Scandinavian countries and Germany, this book is not without fault in leading Professors Bridge and Haddon *a priori* to judge the investigations recorded in my *Lydorganer hos Fiske* to be a mere "theory."

To conclude, I feel bound to point out a deficiency in my observations of the air-bladder as a sound-producing organ. According to the structure of the air-bladder in *Gadus morrhua* and *G. æglefinus*, I had to consider this organ as a sound-producing organ, but a very weak one, because of the slight size of the extrinsic muscles. In both species I irritated, by means of an electric stream, the muscles, as well as the nerves leading to these muscles. But the muscular contractions produced by these operations had only this effect, that the wall of the air-bladder bulged a little inwards and outwards on the place where it was covered by the muscles. But no sound whatever was emitted. The negative result at which I arrived may perhaps be due to the circumstance that I am not accustomed to that kind of experiments. It would, therefore, be most desirable if such an examination were undertaken by an experimental physiologist *ex professo.*

[1] Lectures on the Comp. Anat. and Physiol. of the Vertebrate Animals, Pt. I., p. 278.—On the Anatomy of Vertebrates, Vol. I., p. 497. In the latter book the word "Pogonias" is omitted.

(*To be continued.*)

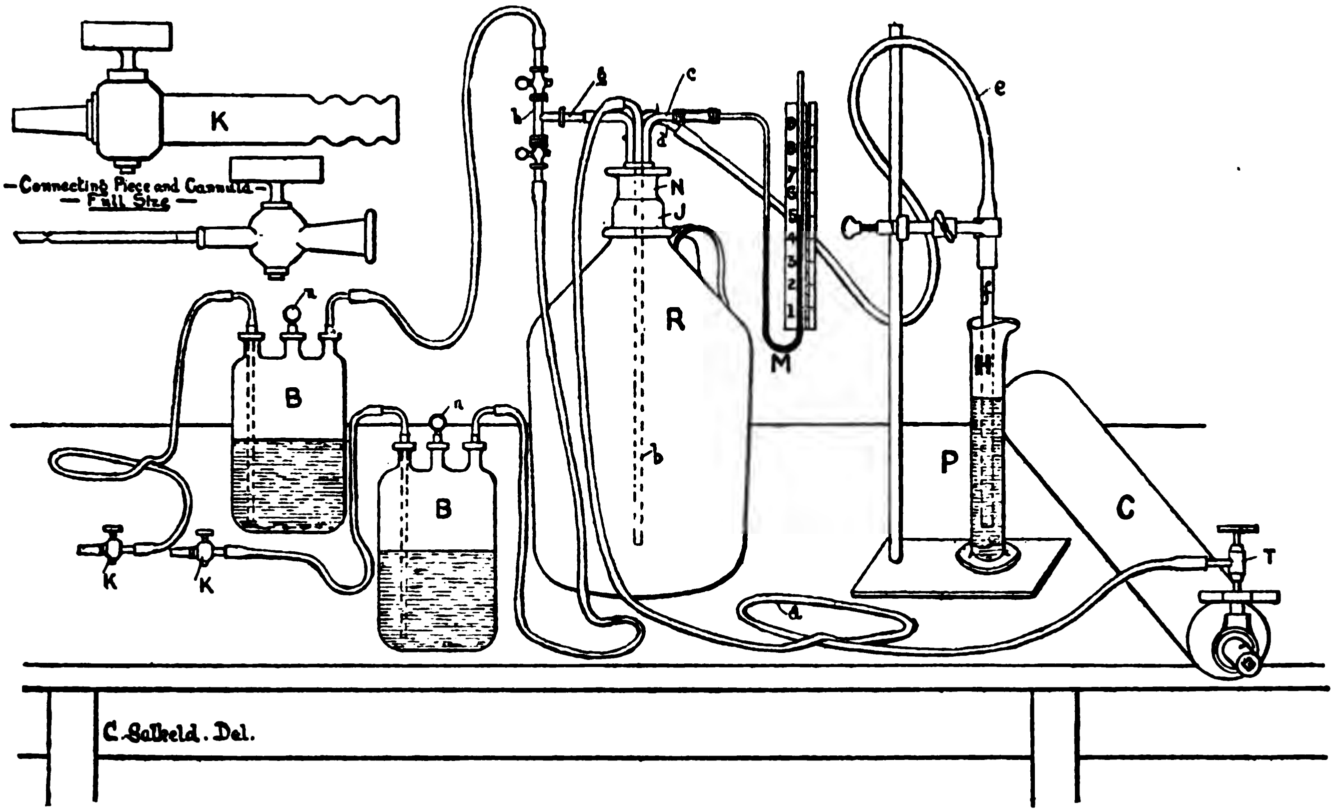
NOTE ON AN INJECTION APPARATUS. By Robt. A Bolam, M.B., B.S., *Demonstrator of Physiology*, and Charles Salkeld, B.A. (Lond.), *Assistant Demonstrator of Physiology University of Durham College of Medicine.*

The apparatus to be described has been in use for some time past in the Physiological Laboratory of the College of Medicine, at Newcastle-upon-Tyne. It is deemed worthy of notice on account of the very satisfactory nature of the gelatine-mass injections which have been obtained by the use of this simple and inexpensive plant. There are, moreover, some points in detail which we venture to think are novel and of decided utility.

Experience of the methods in vogue led to the adoption of what may be termed the direct air-pressure system, as distinguished from those systems in which water is employed to originate the pressure. The foot blow-pipe and ordinary hand-pump have been utilised with greater or less success, but in practice the necessity of some means of producing and maintaining a constant pressure susceptible of easy regulation is constantly felt.

Compressed gas, as supplied in iron cylinders by the Oxygen Company of Manchester, is readily obtained, inexpensive, easy of manipulation, and affords at first hand a far greater pressure than is ever required.

The cylinder of gas, C, should be fitted with the tap regulator, T, supplied by the Company, and now commonly used by lanternists. It is arranged to discharge through thick rubber tubing, *a*, into the pressure reservoir, R. This is simply a 3-gallon stone bottle, which may be had from any druggist for half-a-crown or thereabouts. To obviate corks, use is made of the rubber junction, J, employed by plumbers for the joint between the cistern-pipe and the flush-pipe of an earthenware closet. The wider portion, J, of the junction fits the neck of the stone bottle, and is secured in its place by means of covered wire. The narrow neck, N, of the junction grasps a brass block


K
— Connecting Piece and Cannula —
— Full Size —
B
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n
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K
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a
C. Salkeld. Del.

drilled to receive the various metallic leading tubes, and the joint is again made secure by wiring.

Of the four tubes figured, that from the cylinder alone, *b*, runs down into the interior of the bottle, the others screw into the holes drilled in the block. One of the three latter tubes, *c*, is in connection with the usual manometer, M, which is provided with a movable index. A second, *d*, by a length of rubber tubing, *e*, communicates with the automatic pressure regulator, P. The rubber tubing, *e*, is connected to a long glass tube, *f*, of half an inch bore, graduated in inches, and dipping into a glass cylinder, H, containing mercury. To maintain an equable pressure for a length of time, the tap of the gas cylinder, T, is turned so that a small stream of gas constantly passes into the reservoir. At the same time, the glass tube, *f*, of the pressure regulator is immersed to such a depth in the mercury that when the manometer registers the required pressure gas is just bubbling through the regulator. A greater pressure is got by lowering the tube further into the mercury, and also, if necessary, by increasing the entering stream from the gas cylinder. By depressing the tube in this way, the pressure can be slowly and evenly augmented to any desired extent. Automatic regulation of the injection pressure by this method is very efficient, and in practice is found to be entirely uninfluenced by the rate at which the injection-mass is passing. It is advisable to loosely pack the mouth of the mercury cylinder with flannel, in order to prevent spilling of the contents. Moreover, it may be here noted that compressed coal-gas or hydrogen is much more suitable than oxygen, the latter having an appreciable oxidising action on the mercury in the regulator.

The third tube, *g*, leads off by a T-piece, each limb of which is provided with a tap, and communicates with an injection-mass bottle. Here, again, corks and their inconveniences are dispensed with. Three-necked Woulff's bottles, B (as figured), with two leading tubes ground to fit as stoppers into the necks, can be had from any dealer in chemical glass-ware at a very moderate cost. The third neck, *n*, is provided with a simple stopper, and through it the mass may be filtered into the bottle.

Single or simultaneous double injection can be accomplished at will.

The cannulæ employed do not depart to any extent from the ordinary type. One connecting piece, K, is made to fit all the cannulæ by means of a friction-joint. Both cannulæ and connecting piece are provided with stopcocks,—a point of considerable importance in practice.

The apparatus noted is for the most part constructed of material ready to hand in laboratories. The leading tubes, with their supporting block, can be satisfactorily made by any brass-finisher.

In a more pretentious outfit, the pressure reservoir would be a large metallic vessel, with the various leading tubes soldered into the structure.

The quantity of compressed gas used during an experiment is inconsiderable, and the cost therefore trifling. The pressure can be maintained absolutely constant, the regulator being perfectly automatic. Thus the operator is at liberty to turn his whole attention to other details in the experiment.

VARIATIONS IN THE FORM OF THE THYROID GLAND IN MAN. By C. F. Marshall, M.D., B.Sc., F.R.C.S., *Surgical Registrar to the Hospital for Children, Great Ormond Street.*

The following is a brief account of certain variations in form of the thyroid gland, based on observations of 60 cases collected from children, varying in age from a few weeks up to 10 years.

The original object of these investigations was to obtain further evidence as to the frequency of persistence of any part of the thyro-glossal duct, or of the "canal of His." The results on this point were, however, mainly negative, as in no case was there a persistent thyro-glossal duct present, or any structure of the nature of a "canal of His."

The chief points brought out in this series of cases are, (1) the extreme variation in the gross anatomy of the gland, so much so that to speak of a "normal" thyroid gland is absurd; (2) the frequency of the presence of the processus pyramidalis, this being present, more or less developed, in nearly half the cases; (3) the great variation in size and distinctness of the isthmus; (4) the comparison of the fully developed gland with the latest accounts of its development.

Variations in the Lateral Lobes.—In the large majority of cases the lateral lobes of the gland were approximately equally developed. In about 7 per cent. of the cases only was one lobe markedly larger than the other. In one case out of the 60 the right lobe was absent, apparently entirely, and the gland consisted of left lobe and isthmus (fig. 5).

Variations in the Isthmus.—These concern the extent to which the isthmus is distinct, or more or less fused with one lobe of the gland; and its entire absence. In 6 cases, or 10 per cent., the isthmus was entirely absent (figs. 4 and 12).

In about 75 per cent. of the cases the isthmus was fairly centrally placed; in about 25 per cent. it was more or less fused with one of the lateral lobes. Fig. 2 shows a large isthmus fused with the left lobe of the gland. In fig. 11 the isthmus is

fused with the right lobe. In fig. 3 the isthmus is extremely narrow in its central part.

The Processus Pyramidalis.—The processus pyramidalis was present in 43 per cent. of the cases. In 26 cases in which the pyramid was present, it was attached to the hyoid bone in 17 cases, in the remaining 9 cases it ended in the fascia covering the thyroid cartilage; *i.e.*, attachment to the hyoid bone was twice as frequent as to the thyroid cartilage.

In some cases the pyramid is connected with the isthmus, as in figs. 6 and 7; in other cases it joins what is apparently one of the lateral lobes (figs. 8 and 9).

In one case the lower end of the pyramid bifurcated, one division going to each lateral lobe. The bearings of this on the development of the gland will be considered later (fig. 13).

In one case a double pyramid was present, each terminating on the thyroid cartilage (fig. 17).

The Foramen Cæcum and Ductus lingualis.—In 38 per cent. of the specimens the foramen cæcum was practically absent. In 46 per cent. it was present in the form of a slight pit up to ⅛ inch in extent. In 15 per cent. it was about ¼ inch in length, representing the remains of the *ductus lingualis.*

Comparison of these Variations with the Development of the Gland.—Concerning the development of the thyroid gland, His has shown that it develops in three independently arising parts: (1) A median tubular outgrowth from the ventral wall of the pharynx (*the median thyroid rudiment*), which bifurcates at its lower extremity, forming two lateral lobes at right angles to the main duct. This forms the isthmus and part of each lateral lobe, and, when present, the processus pyramidalis. (2) Two solid lateral outgrowths, which form the main part of the lateral lobes.[1]

Bland Sutton[2] describes the processus pyramidalis as part of the original thyro-glossal duct, or median thyroid rudiment of His; and I have attempted to show that the median cervical fistula, or "canal of His," which is occasionally met with in surgical practice, is a remnant of one of the bifurcations of the median thyroid rudiment.[3]

[1] *Archiv für Anatomie und Entwickelungsgeschichte*, 1891, pp. 26–32.
[2] *Dermoids*, pp. 79–83. [3] *Jour. Anat. and Phys.*, Oct. 1891.

Fig 2

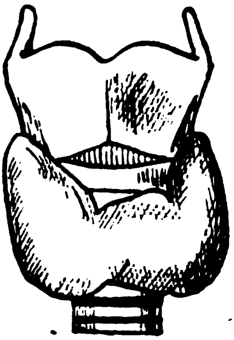


Fig 1

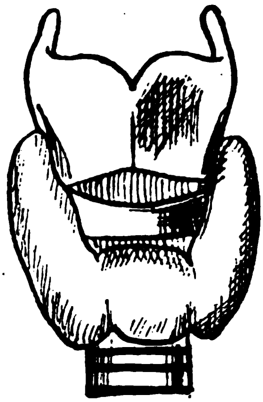


Fig 3

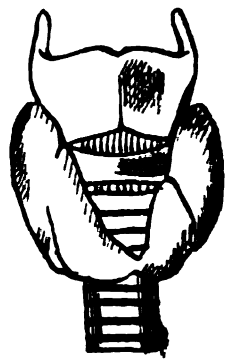


Fig 4

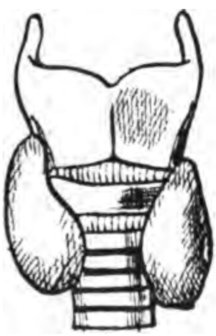


Fig 6

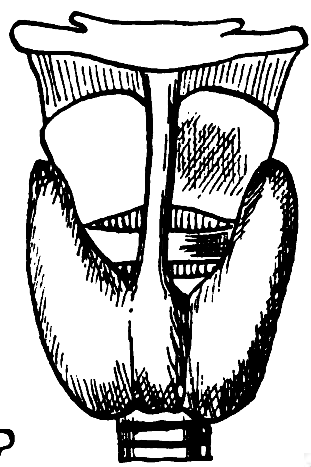


Fig 8

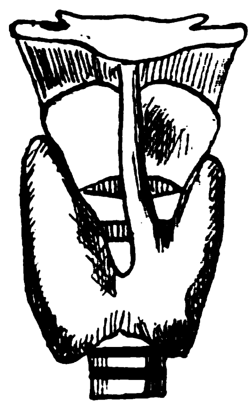


Fig 7

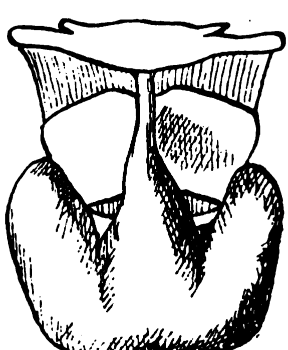


Fig 9

Fig 5

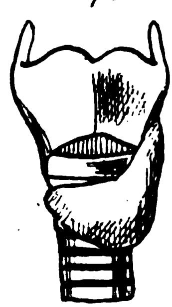


Fig 11

Fig 10

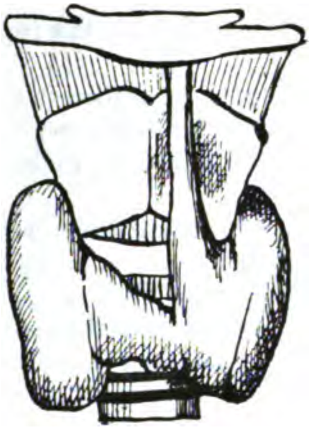


Fig 12

Fig 14

Fig 13

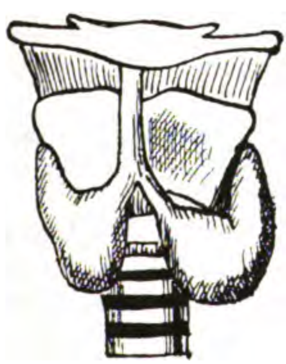


Fig 15

Fig 16

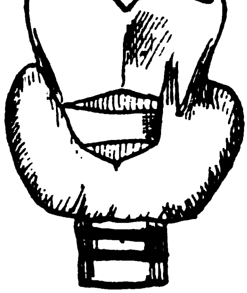
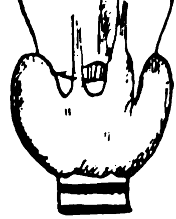


Fig 17



Some of the specimens figured in this paper are of interest in this respect.

(1) Fig. 13, showing the bifurcation of the processus pyramidalis, is of great interest, in that it represents the embryonic bifurcation of the median thyroid rudiment preserved in an adult condition.

In this case there is no true isthmus in the ordinary sense of the term, but the lateral portions of the median rudiment appear to have fused with the lateral lobes.

(2) In most cases the extent of the median rudiment is presumably indicated by the limits of the isthmus when this is distinct. In other cases, as in fig. 11, there is little indication as to its limits.

(3) Fig. 17, in which two pyramids are present, is another remnant of the lower end of the bifurcation of the median thyroid rudiment.

(4) In most cases in which the processus pyramidalis persists, as is seen in the figures, one of the bifurcations of the median rudiment becomes absorbed, and it seems rare for both to persist.

(5) In fig. 12 the median rudiment persists in the form of a pyramidal process which has joined on to the left lobe of the gland; no true isthmus is formed.

It is interesting to note that there is no relation between the extent of the remnant of the ductus lingualis and the presence of the processus pyramidalis, for in the 9 cases in which the ductus lingualis was represented by $\frac{1}{4}$ inch, only 4 of these cases had pyramidal lobes, the other 5 having none at all.

DESCRIPTION OF FIGURES.

Fig. 1. Thyroid gland with lateral lobes equally developed, and well marked isthmus centrally placed. (This corresponds to the average structure described as normal in the text-books.)

Fig. 2. Isthmus abnormally large, and attached chiefly to left lobe of gland. Lateral lobes comparatively small.

Fig. 3. Isthmus very narrow.

Fig. 4. Isthmus entirely absent.

Fig. 5. Right lobe of gland not developed. Isthmus and left lobe present.

Fig. 6. Processus pyramidalis attached to isthmus and to hyoid bone. Lateral lobes equally developed.

Fig. 7. Similar to fig. 6, but with isthmus and base of processus pyramidalis abnormally large.

Fig. 8. Processus pyramidalis attached to hyoid bone and to *left* lobe of gland. Isthmus narrow.

Fig. 9. Processus pyramidalis attached to hyoid bone and to *right* lobe of gland.

Fig. 10. Processus pyramidalis attached to hyoid bone and to left lobe of gland. Isthmus distinct from lobes.

Fig. 11. Processus pyramidalis attached to centre of a mass representing right lobe of gland and isthmus.

Fig. 12. Processus pyramidalis attached to left lobe of gland. Isthmus absent.

Fig. 13. Bifurcation of lower end of processus pyramidalis, one branch going to each lobe of gland.

Fig. 14. Processus pyramidalis arising from right lobe of gland, and ending on thyroid cartilage.

Fig. 15. The same attached to left lobe of gland.

Fig. 16. Rudimentary processus pyramidalis arising from left lobe of gland.

Fig. 17. Double pyramidal processes, arising from isthmus, and ending on thyroid cartilage.

PRELIMINARY NOTE ON INTER- AND INTRA-CELLULAR PASSAGES IN THE LIVER OF THE FROG. By J. W. FRASER, M.D., C.M., M.R.C.S., and E. HEWAT FRASER, M.B., C.M. (PLATE V.)

THE specimens on which these observations are founded were prepared in the following manner:—A frog was injected from the bulbus arteriosus with Hoyer's Lead Chromate Gelatine Mass (*Microtomist's Vade Mecum*, Bolles Lee, 2nd edition, p. 228), at pressures of 1, 2, and 3 inches of mercury respectively; a lobe of the liver being cooled with ice or ether-spray, ligatured and removed at the end of each stage. The vessels appeared to be fully injected at the end of the 1-inch stage, and little change, visible to the naked eye, was produced by the higher pressures.

In another specimen, Carter's Carmine Gelatine Mass was injected at a pressure which was not carefully measured, but which would not exceed 4 inches of mercury. Portions of liver in each case were fixed in spirit, which was found to give better results than mercuric chloride or chromic acid, embedded in paraffin, and cut into $\frac{1}{1000}$-inch sections.

A third liver, and also the stomach and duodenum, were treated by Golgi's Chromo-Osmo-Silver process, and cut embedded in paraffin.

In the case of the chromate injection specimens, the low power showed that all three pressures had well injected the vessels, the degree of distention varying, of course, with the pressure. The appearances with the high power (giving 650 diameters) are shown in figs. II., III., and IV., which were drawn from the microscope with Beale's Neutral Tint Reflector. Fig. II., from a section injected at 1-inch pressure, shows a fine network of injection passing between individual cells, and in many cases piercing their substance: the inter-cellular passages can be readily traced, on the one hand, to the large inter-tubular blood-vessels, and on the other, to the intra-cellular tubes, which can, in some cases, even be traced into the nuclei of the cells, and, whether ending in cell or nucleus, are observed to bear a terminal "knob."

(A good example of an intra-nuclear passage is seen in the upper part of fig. II.) In some cases several points of injection are contained in a single cell. With the 2-inches pressure (fig. III.) the "knobs" are seen to have become more dilated, forming "reservoirs"; a large one, sigmoid in shape, is seen in one of the central cells in the figure, with an intra-cellular passage leading into it, which appears to pass through portions of two cells; this same cell has, in addition, a second passage, ending in the nucleus. In another cell on the right of the figure, an intra-cellular tube leads to a "reservoir" which indents the nucleus, and to the left a cell is seen which shows quite a number of passages cut transversely.

In fig. IV., from a specimen injected at 3-inches pressure, at least four "reservoirs" are seen, and in two cases their communicating tubes going to the inter-cellular passages: one of the reservoirs lies in contact with a nucleus. A transverse section of an inter-tubular blood-vessel is shown in the centre of the figure, with two inter-cellular passages opening out of it. In the upper part of the figure, the hardening action of the spirit has caused three cells to shrink away from the inter-tubular blood-vessel, but has left an inter-cellular passage injected, bridging the gap. It is noticeable that in none of these cases is the lumen of the liver tubule injected.

In the specimen injected with Carter's Carmine Gelatine Mass, as shown in fig. I., a complicated network of intra-cellular passages is seen; two factors helping to produce this more complete result, namely, a higher pressure and a finer injecting mass. In one cell in the upper part of the figure an intra-cellular passage can be traced entering the cell, and dividing so as to surround the nucleus with a ring of injection, as well as sending an intra-nuclear branch into it; in the lower part of the figure a cell shows a large reservoir, with a line of injection passing nearly round the nucleus. The spirit hardening has caused great shrinking of the cell substance, so that some of the "reservoirs" appear to be situated in vacuoles.

The Golgi Chromo-Osmo-Silver process, though so successful in demonstrating capillary bile ducts in the Mammalia, has failed in the present case to show the intra-cellular passages, and only in a few cases are the inter-cellular tubes marked out.

As to the nature of these passages, it is obvious that they are in direct communication with the blood-vessels, though, of course, far too small to transmit the corpuscles. Meyer[1] (*Sitz. der Akad. der Wissenschaft*, Wien, xci. 1, 2) has described similar minute capillaries in the tail of the tadpole, though it does not appear that these are intra-cellular. Adamkiewicz (vide *Lancet*, i. 86, p. 988) has described intra-cellular and intra-nuclear capillaries in the nerve cells of the spinal cord, which, he suggests, are necessary for the nutrition of these cells, on account of their large size. Such, then, may be the function of the passages here described, and the "reservoirs" may be used during the active congestion of the liver which follows digestion, for the storing of serum, highly charged with nutritive material, to be drawn on as required.

Golgi (*Archiv Ital. der Biologie*, xix. p. 448) has described a somewhat similar network of inter- and intra-cellular passages connected with the delomorphic cells of the peptic glands in the stomach of the Mammalia, and also in the liver; the Chromo-Osmo-Silver process did not show these in the epithelium of the frog's stomach, and, as already stated, only very partially in the liver. From his description, these passages in the peptic glands appear to be capillary ducts: such capillary bile ducts (both inter- and intra-cellular) have been described in the frog; and Lahousse (*Archives de Biologie*, vii. 1), while denying the existence of intra-cellular ducts, states that in the rabbit and pigeon the inter-cellular bile capillaries have projections into the cell substance.

Thus it appears that, on the one hand, minute intra-cellular serum capillaries have been described by various observers, and, on the other, minute capillary ducts, both inter- and intra-cellular, but the passages here figured appear to partake of both natures. It is true that, even with a pressure of 3 inches of mercury, the injection was not forced into the lumen of the liver tubules; it remains to be seen whether a higher pressure

[1] Dr Carter described in this *Journal*, November 1869, minute networks in various organs lying in the interspaces of the capillaries and situated between the cells of the part. He named these networks "diaplasmatic," and considered that they united the blood-vascular and lymph-vascular capillaries. He employed as an injecting material the carmine gelatine mass known by his name.—[EDS.]

and a more prolonged experiment will effect this. Whatever the result of this experiment, it has been shown that the blood serum is brought into much closer relation to epithelial cells than has been before understood. Lastly, the appearance in fig. IV., showing an inter-cellular passage bridging a gap, makes it seem probable that these tubes have a proper wall, an hypothesis which is supported by the fact that the higher pressures of injection dilate the "reservoirs" without perceptibly stretching the communicating passages. Various experiments besides those suggested above are required for the full elucidation of the subject, but enough has been shown to justify the publication of this preliminary note on the appearance of bodies which, though easily demonstrated, do not seem yet to have attracted much attention.

THE RUDIMENTARY METACARPAL AND METATARSAL BONES OF THE DOMESTIC RUMINANTS.

By A. E. Mettam, *Professor of Anatomy, Royal Dick Veterinary College, Edinburgh.*

During the past summer I was occupied in working at the development of the os pedis or terminal phalanx and the hoof of ungulates; but material failing me, I resolved to examine the metacarpal and metatarsal regions of certain embryos in my possession. I was prompted to do this because of the great diversity of opinion upon the presence and significance of the so-called "splint bones," not only in veterinary text-books, but also in those works more especially consulted by the comparative anatomist.

Before stating the results obtained, I propose to refer briefly to what is already known on the subject, as detailed in some of the publications before mentioned.

Owen (1), writing of the so-called "cannon bone," says, "it accordingly supports a pair of toes which answer to the third and fourth in the pentadactyle foot . . . . . In the ox, rudiments of the distal parts of the second and fifth digits are appended to the coalesced metatarsals of the functional pairs of toes three and four."

According to Flower (2) "among the Artiodactyles the lateral (second and fifth) metacarpals and digits are generally rudimentary, sometimes completely absent." "Sometimes the hoofs alone (of the second and fifth), as in sheep and oxen, supported, it may be, by irregular nodules of bone, rudiments of the ungual phalanges."

In Strangeway's *Veterinary Anatomy* (3) mention is made of a rudimentary metacarpal placed postero-externally; and similarly in the posterior limb, the small metatarsal when present is rudimentary and single.

In the first English edition of Chauveau's *Comparative Anatomy* (4) we notice "the rudimentary metacarpal is only a small osseous stylet, articulating by a diarthrodial facet, behind and to the outside of the superior extremity of the principal metacarpal: it is sometimes absent in the sheep and goat." On the same page of this work there is the following remarkable statement:—"In Ruminants the metacarpal bones are two in number,—a principal, which itself results from the consolidation of the *second and third metacarpals;* and another, altogether rudimentary." The reference to the metatarsus is on the same lines. In the second English edition we find it stated that a

stylet of bone runs down on either edge of the cannon bone: the external one in the metacarpus is an atrophied metacarpal, because in some instances (teratological) it becomes elongated, and supports a more or less perfect digit. The inner rudimentary metacarpal is said to be smaller, and in a position corresponding to the external, but embedded in a fibrous cord.

In the second edition the remarkable statement that the main element of the metacarpus results from the fusion of the second and third metacarpals is repeated.

If this is the opinion of the author, he must believe that the innermost rudimentary metacarpal is the metacarpal of the pollex, a conclusion which I think few comparative anatomists would support. I believe it is the almost universal opinion that of all the members of the pentadactyloid limb, the thumb is the most unstable. I have not found traces of it in the embryo pigs examined; and of all the Artiodactyles, none could be better for the purpose. I think the weight of evidence adduced from the articulations of the metacarpus with the carpus, the metatarsus with the tarsus, and from the development and arrangement of carpal and tarsal bones, forces us to the conclusion that the coalescing metacarpals and metatarsals are the third and fourth of the manus and pes.

M'Fadyean (5) points out that there are two metacarpals in the ox, the large one representing the combined third and fourth metacarpals, the small one representing the fifth. Regarding the metatarsals he observes that the chief metatarsal results from the fusion of the third and fourth, and that the small bone he figures as a subtarsal sesamoid "may possibly represent the second metatarsal." In many works on Comparative Anatomy and Zoology, illustrations are given of the skeleton of the anterior member of the sheep, showing clearly two rudimentary metacarpals, one on either side of the main bone, and more than a third of its length. The illustration is evidently that of an adult; but there must be a mistake somewhere, because at most only one is found—the external one, and it never exceeds three centimetres in length. Such, at least, is the condition observed in ordinary sheep.[1]

Bateson (6) observes that "it is known that in the embryo sheep rudiments of metacarpals II. and V. exist, which afterwards unite

[1] In the adult ox the length of the fused third and fourth metacarpals averages 20 cm., the fifth metacarpal is only 4 cm. long. The fused third and fourth metatarsals vary from 21 cm. to 24 cm. in length, the second metatarsal, ellipsoidal in outline, measures 2 cm. and 1·5 cm. along its greatest diameters. In adult sheep the fused metacarpals and metatarsals have relatively the same length, *i.e.* 12·5 cm.

with III. and IV. Sometimes these rudiments remain fairly distinct at the proximal end of the cannon bone, especially of the fore foot."

Such are some of the opinions held upon this subject; and while it appears to be known that at one period of the sheep's existence it had four metacarpals and four metatarsals, yet there is no approach to a like consensus of opinion as regards the manus and pes of the ox.

The illustrations in this paper are photographs of sections from an embryo calf that came into my hands from C. Hartley, F.R.C.V.S., of Lincoln. They are arranged so that four of the figures show the metacarpal region and two that of the metatarsus. It may be seen at a glance how the rudimentary bones differ from the two that will eventually fuse to form the cannon bone, and also between themselves.

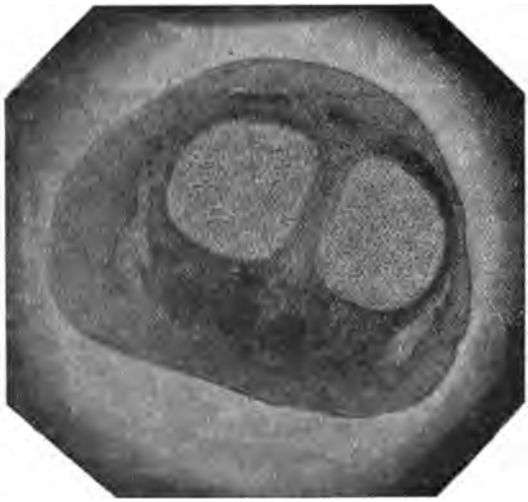
The embryos examined were of various sizes; but since all the most marked features are easily discernible in the embryo I am about to describe, it is unnecessary to refer to them beyond mentioning that the largest was 9 cm. in length. The length of the one under discussion was 5·6 cm.; the length of tail 1·6 cm.; from point of tarsus to tip of toe, 1·15 cm.; from elbow point to distal extremity of the limb, 1·75 cm. As a further important point, and one that bears more especially upon the measurements, it may be mentioned that the exact age is known. The dam received the male on April 7th, at 11 a.m., and the fœtus was aborted on June 11th, at 7 a.m. The parts examined were fixed in corrosive sublimate solution, decalcified, hardened and dehydrated in the usual manner, and cut in paraffin. Transverse sections of the manus were made from the tip of toe to the carpus, 526 sections in all; of the pes, from toe to tarsus, 594 sections in all.

Photographs of sections 301, 425, 456, and 473 of the manus are given, and of sections 387 and 421 of the pes.

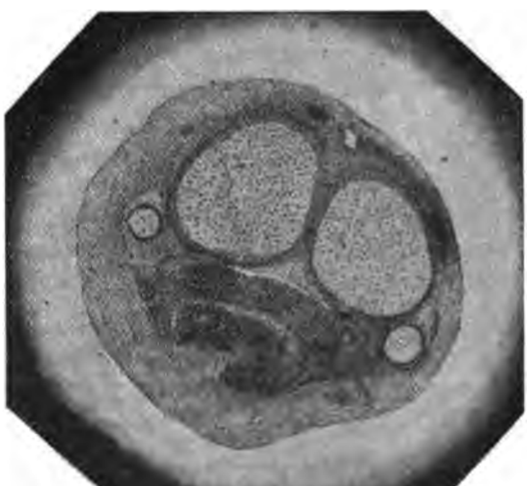
Metacarpus.—Section 301 shows the 3rd and 4th metacarpals in transverse section, and that they are as yet cartilaginous. Flanking these there will be noticed at the postero-lateral angles, inner and outer, two pyriform areas, showing more or less clear in the photographs. These are islands of connective tissue, possessing few connective-tissue corpuscles as compared to the

Manus. Photographic Section 456.

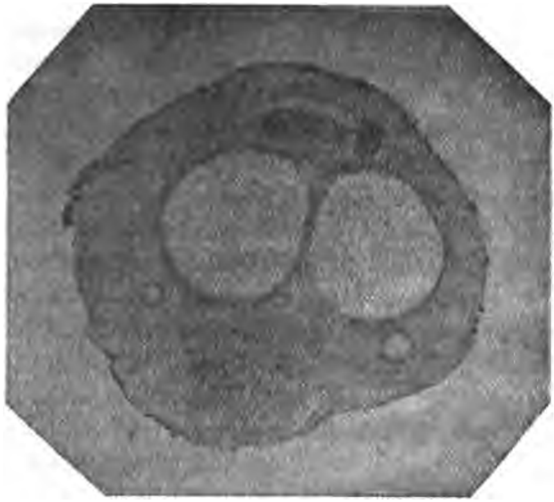
Manus. Photographic Section 473.



Manus. Photographic Section 301.



Manus. Photograph 425.



Pes Section 387.

Pes Section 421.

surrounding structures. They mark the positions occupied by the 2nd and 5th metacarpals in succeeding sections. The antero-posterior diameter of the 3rd and 4th metacarpals at this point is ·629 mm. At section 317 the lower extremity of 5th metacarpal is first clearly seen as an island of cells differentiated from the general structure of the pyriform area of connective tissue in which it appears. The 2nd metacarpal has not yet appeared, and thus it seems that the splint bone found in the adult has, even at this stage, a greater length than the 2nd metacarpal, which is not seen until twelve sections later, then it is observed to come into view in a precisely similar fashion as the 5th, viz., as an island of cells, differentiated from those of the connective tissue in which it appears. The 5th has already attained a diameter of ·102 mm. At section 352 the antero-posterior diameter of the 5th metacarpal is ·153 mm.; of the 2nd, ·085 mm. At section 372 each has increased in size, the 5th to ·17 mm., the 2nd to ·102 mm., and they both are circular in outline. Section 394 shows 2nd metacarpal has become elliptical, with the greater diameter antero-posterior ·17 mm. in length, and it measures at right angles to this ·136 mm. The 5th metacarpal has taken on a similar shape, and its long axis is directed obliquely backwards and inwards, and along this diameter is ·204 mm. in length, its greatest transverse diameter being ·17 mm. From section 394 to section 414 the 2nd metacarpal reaches its maximum size, which it maintains through twenty sections, and after that steadily diminishes. At section 414 it is circular in outline, and with a diameter of ·153 mm.; the 5th metacarpal has a similar appearance, but has increased its size to ·187 mm. in diameter. Section 425 (Photo-micrograph II.) shows the 3rd metacarpal with an antero-posterior diameter of ·68 mm.; of 4th, ·5595 mm.; of 2nd, ·136 mm., and almost circular; of 5th, ·170 mm. antero-posterior diameter, but somewhat elliptical, and measuring along its greatest width ·187 mm. Section 456 (Photograph III.), 3rd metacarpal, has an antero-posterior diameter of ·85 mm.; 4th, of ·612 mm.; 2nd, ·051 mm., and circular in section; 5th, elliptical in outline, greater diameter directed inwards and backwards, measuring along this line ·170 mm. and ·119 mm. at right angles to this. Section 473 (Photograph IV.), showing the 3rd and 4th metacarpals partially fused

with an average antero-posterior diameter of ·765 mm.; there is no trace of the 2nd metacarpal, but the 5th has increased in size, having now a transverse diameter of ·153 mm., an outline as in section 456, and approximately the same length.

Pes.—Sections were made of the left pes, from the extremity of the toe to the point of the os calcis, 594 sections in all. Counting from the first made at the toe, and continuing towards the tarsus, we find at section 306 the first sign of the 2nd metatarsal, and it makes its appearance in a precisely similar fashion as the 5th metacarpal. At section 315 it has attained a diameter of ·051 mm.; the 3rd, behind which it is placed, and the 4th metacarpals are still separate, measuring in the antero-posterior direction ·561 mm. At section 332 the 5th metatarsal appears as a clump of cells differentiated from the connective tissue in which they appear: the 2nd metatarsal has already attained a diameter of ·068 mm.

We may tabulate the measurements in the next three sections, the average antero-posterior dimensions of metatarsals III. and IV. being given. The 2nd metatarsal is gradually becoming elliptical in section.

	Metatarsal II.	Metatarsal V.	Metatarsals III. and IV.
Section 354,	·085 mm.	·051 mm.	·51 mm.
371,	·102 mm.	·0595 mm.	·544 mm.
389,	·136 mm.	·080 mm.	·561 mm.

At section 410 the 5th metatarsal, which up to the present has been placed behind and to the outer side of the 4th, moves forwards and closer to it, the first indication of its ultimate fusion with this metatarsal. Its diameter here is ·085 mm., and from this point it rapidly increases in size until it becomes larger than the 2nd metatarsal, having at section 425 a circular outline and a diameter of ·119 mm., whereas the 2nd metatarsal is elliptical, with a great diameter of ·119 mm., and a short diameter of ·085 mm. The 3rd and 4th metatarsals, which previously have been circular, and separated by a sheet of connective tissue, in this respect agreeing with the 3rd and 4th metacarpals, have elongated in an antero-posterior direction, become somewhat quadrangular, and the connective-tissue plate has become thinner.

On an average, their antero-posterior diameter is ·731 mm. At section 430 the union of the 5th metatarsal with the 4th is complete. The diameter of the 2nd metatarsal is ·170 mm., and the 3rd and 4th metatarsals have almost completely fused. Illustrations of sections 387 and 421 are given, and these will give an idea of the relative size and position of the several metatarsals. From what has been written above, and from the measurements given, it will be seen that the rudimentary metacarpal and metatarsal which persists in the adult is longer than that that disappears. Further, whereas the 2nd metacarpal is spindle-shaped, attaining its greatest size in its length, and tapering to either extremity, the 5th metatarsal is decidedly club-like, thin and tapering below, thick above, and fusing with the 4th metatarsal, and thus adding its share to the volume of the cannon bone. It is interesting to note, also, that the more or less quadrangular cannon bone of the metatarsus takes on its characters so early in fœtal life, the 3rd and 4th metatarsal making a decided step in this direction in the young creatures examined; and they accentuate this, as it were, by elongating in an antero-posterior direction before they fuse, so that when fusion is complete the transverse and antero-posterior diameters are almost equal.

One fact struck me forcibly during the process of measuring and that was, the relatively greater size of the 3rd metacarpal as compared to the 4th metacarpal; and I am inclined to believe that the 3rd contributes more to the bone resulting from their fusion than the 4th. Even in the adult, it is seen that the inner division of the distal extremity of the bone, provided for articulation with the inner first phalanx, is larger than the outer. What is the significance of this I am not prepared at present to assert. It is interesting, however, to observe that there are in the manus and pes of the ox and sheep, at one period of their existence, four metacarpals and metatarsals, and that of these the 3rd is apparently the largest, and that the 2nd metacarpal and 5th metatarsal are unstable and soon disappear, probably fusing with the bone next to which they lie. If, through some error in development, or from some cause not yet ascertained, nourishment is diverted to these otherwise rudimentary structures, may it not be possible and probable that a "monstrosity" would arise?

The demonstration of rudimentary structures that more or less disappear in the adult, may have an important bearing on teratological questions.

I wish to offer my hearty thanks to Professor Ewart, of the University, for allowing me the use of his laboratory, and for help in many ways when I was exceedingly pushed for time; and to Mr F. J. Cole, for his kind assistance, guidance, and advice when taking the micro-photographs.

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OBSERVATIONS UPON THE URINARY BLADDER AND URETHRA.

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PART III. PHYSIOLOGICAL.

(*Continued from* Vol. XXIX. p. 61.)

Rhythmical Variations in the Tonicity of the Wall of the Bladder.

RHYTHMICAL contractions, followed by relaxations of equal extent, are found to occur, to a more or less degree, in all unstriped muscle. In the ureter, for example, there is a distinct rhythmical contraction, followed by relaxation,—the contraction-phase being directly observable by the naked eye, and indirectly by watching the mode in which a drop of urine is projected from the mouth of the ureter into the bladder. But in the bladder the contraction and relaxation of its muscular wall, though taking place rhythmically and regularly, are much less pronounced. Indeed, neither the contraction nor the relaxation can be observed directly by the naked eye, and they can only be demonstrated and studied by a suitable recording apparatus, by means of which slight variations, both in the pressure of the contained urine and in the volume of the bladder, may be detected.

Therefore, as the contractions and relaxations of the muscular wall of the bladder are so slight as to escape notice by the naked eye, these phases may perhaps be best described as variations in tonicity—an increase in which would correspond to a contraction, and a decrease to a relaxation. The difference, then, between an increase of tonicity and a contraction is merely one of degree, and not of kind.

The following simple method of observation was adopted:—A small water manometer, as supplied by the Cambridge Scientific Instrument Company, was connected with the bladder by means of a glass cannula and a short length of india-rubber tubing passed through the urethra. On the water in the free limb of the manometer a float, consisting of cork well soaked in paraffin, was placed. To the centre of this cork a thin wire stilette was fixed, and carried through a central hole in the cap over the free end of the manometer tube. Fixed to the upper and free end of the stilette was a short horizontal limb bearing a fine writing-quill point which marked upon blacked paper on a slowly revolving drum.

The rhythmical variations in the tonicity of the wall of the urinary bladder were first observed and described by the late Dr Ashdown (1), who noticed them while conducting some experiments for the purpose of determining the absorption-power of the vesical mucous membrane. He found that the extent and rhythm of the variations could be altered by the introduction of irritating substances into the urine contained in the bladder. For example, an injection of a weak solution of hydrochloric acid (1 per cent.) in water was soon followed by irregularity in the rhythm and diminution in the extent of the variations; an alkaline solution produced the same changes; but a neutral solution interfered neither with the regularity of the rhythm nor with the extent of the variations.

Mosso and Pellicani (2), in a conjoint paper, give an account of similar rhythmical contractions and relaxations which they observed; and they obtained tracings of them in the dog, and also in two young women. In the dog, and also in the women, no anæsthetic was used, for the procedure was painless, and without any risk of danger. They found that in the dog even the sight of a piece of bread and such-like mental stimuli produced contraction of the bladder; and in the women, pinching the arm, &c., produced the like effects. With regard to the influence of cerebral activity upon the bladder, they conclude that: "*Tout fait psychique, et tout travail mental, est toujours accompagné d'une contraction de la vessie.*"

Similar contractions and relaxations of the bladder-wall also occur in the frog and cat, and probably in all animals. In the monkey I had occasion, while conducting some experiments with Dr Sherrington, to note that these rhythmical variations occurred with great regularity.

To maintain regularity of rhythm, it is necessary to guard the bladder-wall from the injurious influence of cold air which soon causes the bladder to contract and its walls to become more or less rigid. Chloroform, however, when administered in the usual way, causes the bladder-wall to become relaxed, and, after a time, the rhythmical variations in tonicity to cease altogether, the bladder becoming quite flaccid. In each instance the contractions and relaxations cease after a time; but in exposure to cold air they cease because of undue contraction, whereas in chloroform anæsthesia they cease because of undue relaxation of the bladder-wall. The effect of chloroform is the same as that produced by division of the spinal cord or pelvic splanchnic nerves, and by shock or collapse. Chloroform has also the same effect upon the human subject; for I have noticed this flaccid state of the human bladder where the patient is under chloroform, and indeed in ether narcosis on several occasions during the performance of laparotomy. The rhythmical contractions and relaxations occur whether the bladder is nearly empty or full, and, so far as my observations go, they are best seen in the moderately distended organ. That these variations occur in the bladder-wall, and are not due to changes in the intra-abdominal pressure, is clearly shown by the fact that they continue without any alteration after the abdominal cavity is opened and the bladder fully exposed and protected from any extraneous influence.

Accordingly, the muscular wall of the bladder is constantly undergoing rhythmical changes in its tonicity. The extent of the changes may be increased or diminished in various ways, such as by the presence of irritating substances in the urine, under chloroform narcosis, and under different forms of psychical activity. When we come to consider the act of micturition, we shall see that these various causes, which alter the tonicity of the bladder-wall, play an important part in determining the time at which the bladder is urged to expel its contents.

Intra-vesical Pressure.

The intra-vesical pressure is the pressure of the urine in the bladder at any given time, whether the organ be nearly empty or fully distended.

This pressure may be resolved into—(1) that which is produced by the weight of the column of urine (the hydrostatic pressure), and (2) that which is exerted by the muscular wall of the organ upon the contained urine. The former (hydrostatic pressure) is constant for any given quantity of urine, varying only to a slight degree with the posture of the body and the specific gravity of the fluid; whereas the latter (the pressure exerted by the bladder-wall) is ever changing, and that in a direct proportion to the contraction and relaxation of the muscular wall of the bladder. Seeing that the hydrostatic pressure of the urine is practically constant for any given quantity contained in the bladder, it may be disregarded while we are considering that pressure which is exerted by the varying degrees of tonicity of the muscular walls of the bladder.

The method which was adopted to determine the amount of intra-vesical pressure is a very simple one. In all the experiments the abdominal cavity was laid open, the bladder exposed, and thus rendered free from any pressure-influences outside itself, while it was protected from cold by the regulated temperature of the room. Here, therefore, there was no possibility of the intra-vesical pressure being either augmented or diminished by the contraction or relaxation of the abdominal muscles.

Having exposed the bladder and urethra in the way already described (see vol. xxix. p. 66), a small glass cannula was inserted into the bladder through an opening made in the urethra, just in front of, or distal to, the prostate gland where it was firmly secured by a ligature. The cannula was then connected by means of a short piece of narrow india-rubber tubing with a T-tube, connected by one limb with an upright narrow glass tube graduated into inches, and by the other (lateral) with a reservoir holding warm water. The reservoir was only used for distending or emptying the bladder as required, being at other times shut off. The *zero* line on the graduated tube was so adjusted as to be on a level with the lowermost part of the bladder, so that with every given distension of the organ the hydrostatic pressure could be read off and subtracted from the total, or intra-vesical pressure.

When the animal was quiet and the bladder in a natural state, with the rhythmical contractions and relaxations going on regularly, the intra-vesical pressure was scarcely ever more than ½—1 inch of water higher than the hydrostatic pressure alone. And with each contraction and relaxation of the muscular wall

of the bladder, the pressure varied up and down through a range which rarely exceeded half an inch. For example, the total intra-vesical pressure in a dog, with a moderately-distended bladder, was about 2 inches of water. From an inch to an inch and a half of this was the result of hydrostatic pressure, half to one inch alone being the effect of the pressure exerted by the wall of the bladder upon the contained urine. Further, this intra-vesical pressure does not vary with the degree of distension of the bladder except in so far as the hydrostatic pressure influences it. For the pressure, in addition to the hydrostatic pressure, is often the same when the organ contains only a small quantity of urine as when it is fully distended. There is, however, a limit to this distension without a corresponding increase of intra-vesical pressure, and beyond that limit the intra-vesical pressure varies directly with the distension of the organ. This limit is known as the *physiological* limit, beyond which the muscular wall loses its power of contraction, probably from over-stretching of the individual muscular fibres, and the bladder-wall then behaves just like any other simple elastic membrane. It is probable that in cases of retention of urine in Man from mechanical interference with the outflow of urine, as seen in stricture and in enlargement of the prostate gland, the pressure does not rise, except when the bladder wall contracts and endeavours to expel its contents, much beyond that produced by the hydrostatic pressure of the urine until the physiological limit of distension is reached; then the pressure increases independently of the hydrostatic pressure with every additional drop of urine that is forced into the bladder by the contraction of the ureters. The ureters continue to force urine into the bladder, and so help to raise the intra-vesical pressure until it reaches a point at which it overcomes the resistance offered by the urethra to the outflow of urine, and a continuous dribbling of urine is then established.

But although the degree of pressure exerted by the muscular wall of the bladder upon the urine while it is being collected is so small as to be almost insignificant, yet it may become at any moment considerable, for it is dependent upon the degree of tonicity of the bladder-wall; that is to say, it is dependent upon the contraction and relaxation of the muscular fibres. The contraction of the wall may be increased so much as to render

the bladder a firm, tense ball; on the other hand, the relaxation may become so marked that the organ gets to be soft and flaccid, like an ill-filled bag. For example, if a moderately distended bladder, which is undergoing the normal rhythmical contractions and relaxations, be exposed to the influence of cold air, the contractions quickly increase and the relaxations diminish in an equal proportion, so that after a comparatively short time the bladder-wall becomes firm and rigid, and the intra-vesical pressure increased by 2–3 or more inches of water. On the other hand, during the administration of chloroform, the drug being pushed so far as to induce profound anæsthesia, the contractions gradually diminish, and the bladder-wall becomes relaxed, until it is quite flaccid, the intra-vesical pressure falling until it hardly measures more than the hydrostatic pressure alone. Again, if warm water be injected into the bladder by raising the level of the reservoir, say, to 15 or even 20 inches of water, according to the resistance offered by the walls of the bladder to distension, the water can at first only be retained by maintaining that pressure in the upright tube; but soon relaxation of the muscular fibres sets in, and this high pressure gradually diminishes until the intra-vesical pressure is again at its old level; the muscular wall, as it were, giving way, and the bladder accommodating itself to the increased amount of urine. This power of the muscular wall of the bladder to accommodate itself to an increased amount of urine is of great importance, and it is exemplified in those daily occurrences in which, when the bladder is full, after an intense, and may be even a painful desire to micturate, the bladder quiets itself, and settles down to tolerate more urine. This may be repeated again and again several times.

Dubois (3), in his researches on the intra-vesical pressure in the human subject, found that it usually measured from 10–13 cm. (4–6 inches), and that this was more or less constant within a certain limit of distension of the organ; and that beyond that limit,—the *physiological* limit, as it is called,—the intra-vesical pressure varied almost directly with the degree of distension, so that the more the bladder was distended, the greater the intra-vesical pressure became. My results in the dog agree very closely with those found by this writer in the human subject. Further, he found that, in cases of abnormal

retention of urine from mechanical causes in the urethra and from diseases of the spinal cord, the intra-vesical pressure may rise to 30–40 cm. (12–16 inches), and that in cases of coma the pressure became reduced to a minimum.

Mosso and Pellicani (2) showed that the degree of intra-vesical pressure does not depend upon the degree of distension of the bladder, and they were the first to note the facility with which the muscular wall of the bladder is capable of accommodating itself to an increased quantity of water injected under pressure. This they noted both in the dog and in the two women on whom they experimented. Indeed, this is a matter of common experience to surgeons. For, when a bland warm fluid is injected into the bladder, the muscular wall often contracts sharply,—sometimes so sharply, indeed, as to give rise to some pain. Soon, however, the pain passes off, even if the injected fluid be kept in, and the bladder settles down and quickly regains its power of retaining this new quantity of water so suddenly forced upon it.

From a study of the foregoing, we may therefore conclude that (1) the normal intra-vesical pressure in the moderately distended bladder of a dog rarely exceeds 2 inches of water, the greater part of which is hydrostatic in origin; (2) the pressure varies directly with the degree of tonicity of the muscular walls of the bladder, and not with the degree of distension, provided the distension be within the physiological limit; (3) when the physiological limit of distension is exceeded, then the pressure varies directly with the degree of distension.

The Resistance offered by the Urethra to the outflow of Urine from the Bladder.

The simplest method of determining the amount of resistance offered by the urethra to the outflow of urine is that in which a long narrow glass cannula is introduced into the bladder along the ureter: the cannula is tightly secured in its place by a ligature and connected by means of a piece of india-rubber tubing with a movable reservoir of water. By raising the reservoir to a certain height, which varies according to the tonicity of the muscular wall of the bladder, the water by its own weight

passes into the bladder; and if the reservoir be further raised, the intra-vesical pressure will become equal to, and after a time even greater than, the resistance offered by the urethra: when it is greater, the urine will dribble from the meatus urinarius. The height of the level of the fluid in the reservoir above the base of the bladder at the time when the urine begins to dribble gives, approximately, the urethral resistance measured in so many inches of water.

From a series of experiments carried out according to the above method, the following results were obtained. The account of one, given in detail, will suffice.

EXP.—*A full-grown Fox-terrier under the combined influence of Morphia and Chloroform.*

		Intra-vesical pressure.	Pressure required to cause dribbling from the Urethra.
April 1st. 4 p.m.	...	6 in.	16 in.
4.15 p.m.	Divided both Pelvic Splanchnics.	1 in.	18 in.
4.30 p.m.	Divided Hypogastric Nerve.	1½–2 in.	16½ in.
5 p.m.	Pudic Nerves divided.	4 in.	17 in.
5.15 p.m.	...	4 in.	19 in.
5.30 p.m.	Killed by opening aorta.		
April 2nd. 8 a.m.	...	2 in.	16 in.
8.15 a.m.	...	2 in.	2½–3 in.

We find that during life the resistance offered by the urethra of a male dog of medium size varies from 16 to 20 inches of water. The resistance remains the same after division of both pelvic splanchnic nerves, and also after division of both

hypogastric nerves. Even division of the pudic nerves which supply the striped muscle of the urethra, and indeed division of the spinal cord in the dorso-lumbar region, causes no diminution in the resistance offered by the urethra. Further, this resistance is the same after death as during life, whether tried within an hour after death, or from 16 to 20 hours later, when rigor had, in my experiments, passed away. It is necessary, however, to add that the resistance after death is the same only on the first occasion the experiment is tried, for in every subsequent trial the resistance was found to be only an inch or two instead of from 16 to 20 inches. This may be, and probably is, explained on the ground that, when once the urethra is forced open after death, it does not, owing to the loss of contractile power in its muscular walls, close itself, but remains more or less open. Accordingly, the first time it is necessary to force open the urethra, but afterwards the walls remain apart, being unable to close from loss of its muscular contraction as well as absence of elasticity; and the urethra is, under such conditions, occupied by a column of fluid water or urine. Such a column, however small, reduces the resistance to a minimum.

In short, the resistance offered by the urethra to the outflow of urine is the same in the living as in the dead subject at the first trial, and it remains the same after the striped muscles of the urethra are paralysed either by division of the pudic nerves, or even by division of the lumbar part of the spinal cord.

The chief part of the resistance offered by the urethra to the escape of water under pressure from the bladder is no doubt encountered at the junction of the bladder and urethra, urethro-vesical orifice, the remainder and smaller part being offered by the urethra itself. That the chief resistance is at the urethro-vesical orifice is shown by the fact that, in surgical operations, the urethra may be cut up to the neck of the bladder without any escape of urine, but if the neck be incised, then the urine at once escapes. Again, in the cat, duly anæsthetised, the urethra between the neck of the bladder and the prostate gland, which portion in this animal is from 1 to 1½ inches in length, may be divided completely across, and though the bladder be fully distended with urine, none of it escapes. Thus we may assume that it is the wall of the opening of the urethral tube at its

commencement that gives rise to the greater part of the resistance.

That this resistance, both during life and after death, is in the main physical, seems to be shown by the fact that it remains the same after death on the first occasion tried, even after the subsidence of rigor, as during life. This would hardly be the case were it dependent upon some vital or tonic muscular contraction. Further, it appears to be due to the apposition of the moist mucous surfaces along the whole length of the urethra, as well as at the urethro-vesical orifice, together with the unexpanded condition of the surrounding tissues. This condition of the mucous surfaces and of the other tissues, both in the urethra and at the urethro-vesical orifice, is dependent upon muscular action. Once, however, this condition is produced, and the mucous surfaces are apposed, there is apparently no necessity for the muscular fibres to continue either in a state of contraction or in one of tonicity, so as to maintain the closed state, though they may be called into action under special circumstances.

In the urethra the unstriped muscles, as well as the striped external sphincter of Henle and the constrictor urethræ, suffice effectively to close the urethra after each act of micturition. At the urethro-vesical orifice, though there are no striped fibres and no special and circularly disposed unstriped muscular fibres (see "Observations on the Urinary Bladder and Urethra" by me, *Jour. Anat. and Phys.*, vol. xxv.) deserving the name of internal sphincter vesicæ, yet the muscular walls of the bladder are continued, at this junction, along the internal surface of the urethra, the innermost or longitudinal fibres being continued in their longitudinal direction through the urethro-vesical orifice into the urethra, the middle or circular fibres being continued in the same course in their circular direction. There is no special thickening of either of these two layers to constitute what would be called a sphincter. But the muscular fibres thus arranged suffice to effect the purpose of closing the orifice. For a further account of this, see vol. xxv. of this *Journal*, page 544.

Thus there is in the whole length of the urethra, including the urethro-vesical orifice, to the external meatus in both sexes, a muscular wall which is capable of bringing the moist mucous surfaces into apposition at the end of each act of micturition. By

means of this muscular wall the urethro-vesical orifice as well as the urethra itself is closed; and once closed, it remains so until forced apart. During life, closure takes place after each separation and stretching caused by the passage of urine; but after death, when once the orifice as well as the urethral tube is forced apart, it remains open, having lost all muscular power, and there being no elasticity sufficient to bring the surfaces again into contact. This constitutes the difference between the urethra in the living and in the dead subject.

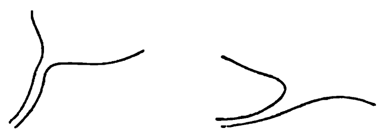
I do not refer here to the nerve influence, reflex or voluntary, by which these various muscular fibres are influenced.

All writers on this subject agree that the chief resistance to the outflow of urine from the bladder, under natural conditions, is at the urethro-vesical orifice. Some, and among them are Budge, Heidenhain and Colberg, Sauer and Uffelmann, attribute the resistance at this orifice to the action of a special muscle, internal sphincter-vesicæ, surrounding the neck of the bladder, while others attribute it to the influence of the external sphincter-vesicæ of Henle. I am unable to agree with the former, because there does not exist a special muscular thickening or sphincter, the effect being sufficiently performed by the ordinary muscular wall of the urethra and urethro-vesical orifice. Still less can I agree with the latter, for the external sphincter-vesicæ of Henle does not commence at the urethro-vesical orifice, even in Man; and in some of the lower animals, such as the cat, it only begins at a distance of 1 to 1½ inches from this point. It must not, however, be assumed from this statement that the external sphincter-vesicæ of Henle, and its continuation as the constrictor urethræ, are incapable of preventing, either voluntarily or reflexly, the further escape of urine along the urethra when once it has commenced to pass into the urethra. Indeed, as will be pointed out further on, one important use of this continuous sheet (ext. sphincter of Henle and constrictor urethræ) is to constrict the urethra at and beyond the apex, or anterior end, of the prostate gland. It may also, under certain circumstances, arrest its progress.

The manner in which the contraction of the bladder is capable of overcoming the resistance at the urethro-vesical orifice may, it seems to me, be explained by a study of the form and shape

of the junction between the bladder and urethra, and this may best be done in the human subject.

If a distended human bladder, in the male or female, be opened from above in the dead subject, and the urethral orifice be examined, it will be seen that it is somewhat funnel-shaped. In the male the funnel-like appearance is less obvious than in the female, owing to the greater prominence, and consequently the greater projection upwards, of the luette vesicale. And if a mesial and vertical section of the bladder and urethra be made after hardening the organs *in situ*, and before they are disturbed, this funnel-shaped orifice of the bladder is much better seen (see figs. 1 and 2). This is also the case in all the animals



Male. Fig. 1. Female. Fig. 2.

FIGS. 1 and 2 show the outline of the urethro-vesical orifice as seen in mesial frozen sections in the male and female respectively.

I have examined. It is, I believe, owing to this funnel-shaped orifice that the bladder is capable, with comparative ease, of forcing open the urethra. The resistance offered by the apposed moist walls would be very difficult to overcome without some such contrivance as this at the neck of the bladder.

In the male and in the female the force necessary to open the urethra is probably very nearly the same, but, owing to the difference in the length of the urethra, there is a difference in the total resistance, which, after the first opening of the urethra, is directly proportional to the length of the tube.

It is, however, maintained by Kohlrausch (4) that the fibres of the detrusor urinæ, or the external longitudinal muscular fibres of the bladder, are inserted at right angles into the internal sphincter vesicæ, and he supposes that the neck of the bladder is opened by the longitudinal muscular fibres pulling the fibres of the sphincter, and so the sides of the urethro-vesical orifice, apart. The majority of the external longitudinal muscular fibres of the bladder, if carefully traced, will be found to change

their direction, becoming oblique and transverse, before they reach the neck; and they are thus not inserted into the exterior of the urethro-vesical orifice in such a manner as to be capable of pulling the walls of the orifice apart.

The current view, however, is that as the bladder-wall contracts, the circularly disposed muscular fibres at the neck of the bladder, and around the commencement of the urethra relax and allow the urine to pass outwards, and that during the natural retention of urine these circularly disposed fibres (internal sphincter) are in a state of contraction, or tonicity. Thus, while the muscular wall of the bladder contracts, the so-called urethral sphincter-vesicæ relaxes; and while the bladder-wall relaxes the sphincter contracts, and remains in that state until the next emptying of the bladder.

I would maintain, however, that, under ordinary circumstances, the muscular wall of the urethra (unstriped) does not undergo active relaxation while the bladder contracts to expel its contents, but simply yields, and that contraction of this muscle takes place at the end of micturition—being a continuation of the contraction of the bladder, which commences above at the fundus, and proceeds in a wave-like manner downwards until it ultimately reaches the urethra. The sudden emptying of the urethra at the end of each act of micturition is, as is well known, the result of the contraction in regular sequence of what I have, in this paper, termed the pelvic group of striped muscle.

The Natural Retention of Urine.

The natural or normal retention of urine depends upon each of the two factors considered in detail and by themselves in the preceding pages. It depends (1) upon the state of the muscle in the wall of the bladder during the accumulation of urine; and (2) upon the resistance offered by the urethra to the outflow of urine from the bladder.

It has been shown that during the accumulation of urine the muscular walls of the bladder are ever undergoing a rhythmical contraction followed by relaxation, and that during the accumulation the latter phase exceeds the former; for the intra-vesical pressure rarely exceeds in the dog more than one-half to one

inch of water above the hydrostatic pressure alone; and does not, be it noted, vary with the degree of distension of the bladder, but with the degree of contraction or tonicity of the muscular fibres. Thus, until the bladder actually contracts upon its contents, the resistance necessary to prevent escape of urine by the urethra is only little more than the equivalent of the height of the column of urine at the time in the bladder, that being, perhaps, three to four inches of water. It has also been shown above that this pressure and more can be easily resisted by the urethra after death when both the striped muscles around it and the unstriped muscles in its walls are no longer in a state of activity.

I do not wish it to be inferred that there exist no *special* muscular mechanisms for the control of the escape of urine; all I wish to say and emphasise here is, that these muscular mechanisms are not ordinarily exercised in the normal retention of urine, and, indeed, are not essential to it. What part the striped muscle of the urethra actually plays in the complex act of micturition, and in the prevention of the escape of urine at undesirable times, will be discussed further on.

What is, perhaps, the most essential factor in the normal retention of urine has not hitherto, it seems to me, received sufficient attention; that is, that the pressure of the urine in the bladder, when retained in small or large quantities, exceeds but little the mere hydrostatic pressure. The amount of pressure in excess of the hydrostatic in any given case is exerted by the muscular walls; and whether the organ be nearly empty or pretty fully distended, this portion of the total pressure usually remains small, and much the same. This is so in the dog, and we have reason to suppose it is not different in the human subject—indeed, the investigations of Mosso and Pellicani (2) on the human subject already referred to show this to be the case. Therefore, the bladder-walls undergo not only dilatation but also an actual relaxation during the accumulation of urine, the muscular fibres accommodating themselves to the increased quantity of urine. This power has its limit, but that limit is not reached under normal conditions.

Thus the urine is naturally retained in virtue of (1) the physical resistance to the opening of the urethro-vesical orifice; and

(2) to the muscular wall of the bladder relaxing and accommodating itself to the increased quantity of urine without causing an increase in the intra-vesical pressure beyond the hydrostatic.

Micturition.

Hitherto the idea of a special sphincter muscle at the neck of the bladder, or commencement of the urethra, has dominated all views regarding the act of micturition. The idea of such a sphincter muscle is very old, and ever since the time of Galen a sphincter has been described with but little variation. Both anatomists and physiologists regard the existence of this muscle as essential to the normal retention of urine; and they conceive that in order to allow of the opening of the urethra it is necessary that the muscle should either be pulled apart or undergo an active relaxation just at the time when the bladder as a whole is contracting to expel its contents. The former view, namely, that which holds that the sphincter muscle is pulled apart, is strongly advocated by Kohlrausch (4); and the latter, the physiological theory as it may be called, which is well expressed in the following words of one of our earliest anatomists, Vicary (5), "whose (bladder) neck is carnous and hath muscles to withhold and let go," is the view at the present time. According to the latter view, the sphincter remains contracted while the bladder is accumulating urine, and becomes relaxed while it (the bladder) contracts to expel its contents. Thus there is supposed to be a true antagonism between the sphincter muscle and the muscular wall of the bladder, the one in a state of contraction while the other is in a state of relaxation, and *vice versâ.*

The two views are based upon the assumption that there exists a sphincter muscle at the neck of the bladder or very commencement of the urethra. If, however, as I have said before, the bladder and urethra of vertebrates, from the lowest to the highest form, be examined, I venture to assert that such a sphincter (internal sphincter vesicæ) muscle, that is to say, a special thickening of the walls of the urethra, as is at present described by anatomists and accepted by physiologists, will not be found. If the bladder and urethra of a tortoise, or better still those of a turtle, be examined, no trace of a sphincter muscle can be found, the muscular wall of the bladder diminish-

ing somewhat suddenly at the neck. The bladder in these animals is just as capable of retaining urine as it is in Man; and as there is no sphincter vesicæ in them, so likewise there is none in all the higher vertebrates, Man included. Many physiologists have, however, disregarded the *internal sphincter vesicæ*, and thrown the work that it is supposed to perform upon the external sphincter of Henle. This external sphincter of Henle, it must be remembered, is merely the beginning of a sheet of striped muscle that surrounds a portion of the urethra, which portion extends from the opening of the genital ducts (vasa deferentia) to the root of the penis; and it (external sphincter of Henle) is only found on the ventral or anterior surface of the urethra, so far as the prostatic portion is concerned; further forward, however, it embraces the whole urethra, and acquires the name of constrictor urethræ. Thus the constrictor urethræ is the only portion of this sheet of muscle in the pelvis that can, properly speaking, constrict the urethra, and thereby control any flow along its channel. But this muscle does not reach to the neck of the bladder, where the chief resistance to the outflow of urine from the bladder exists, as has already been pointed out.

Thus, whatever part the striped muscle of the urethra may play in the mechanism of micturition, it would seem pretty clear that it is not essential to the natural retention of urine.

In order to trace step by step the different stages in the development of the complex act of micturition, it will be as well to consider, in the first place, the act in the newly-born infant, then in the child, and lastly in the adult. The act is the same in the male and female, and what is herein stated applies equally to both. There are, it is true, some peculiarities to be noticed in the male; they are, however, of no consequence in the study of the normal act, but only in the study of abnormal conditions with which I propose to deal in a subsequent paper.

In the *newly-born infant* the act of micturition is at its simplest, and belongs to that class of actions known as "automatic."

The bladder accumulates a small quantity of urine, and then expels it. Soon after birth this emptying is repeated at intervals of *one*, or, it may be, two hours. As the infant grows, the bladder becomes more tolerant, and the amount of urine it is capable of holding becomes greater; and as this tolerance on the

part of the bladder increases, so does the interval between each act of micturition. This accumulation and expulsion of urine goes on more or less automatically until the child acquires consciousness of the act, the time at which this develops being dependent upon health and degree of intelligence. Usually it occurs somewhere about the end of the first year.

Up to this time the act of micturition is the result of what I venture to call a *spontaneous* or automatic reflex. That is to say, when the bladder is distended to the degree to which it is accustomed, the terminal ends of the vesical nerves are stimulated,—whether by the overstretching of the mucous membrane or of the muscular fibres in the wall one can only at present conjecture. The stimulus thus set up passes along the pelvic splanchnic nerves to the lumbo-sacral part of the spinal cord, whence it is reflected along the same nerves and gives rise to uniform and bilateral contraction of the bladder. The time at which this *spontaneous* reflex arises under normal conditions may, to a considerable degree, be regulated by habit.

Thus there is in the newly-born infant a simple reflex which may subsequently be regulated to a great extent by habit. As is generally recognised, the time at which this reflex is set up in the adult is largely determined by habit, and without much inconvenience the times may be changed, and the bladder will soon accustom itself to new conditions.

Although this *spontaneous* reflex recurs at more or less regular intervals in the child, yet a reflex contraction of the bladder may at any time be very readily induced. The occurrence of other than automatic or spontaneous reflex leads me to make some remarks upon the centre that controls the movements of the bladder. Such a centre has been proved to exist by the researches of Budge (6), Gianuzzi (7), and Goltz (8), who locate it in the lumbo-sacral enlargement. Goltz found that after division of the spinal cord (in the dog) in the dorsal region this centre, as well as others in the severed portion of the spinal cord, regains its power which is temporarily lost, probably from the effects of shock. I am inclined to go further, and even suggest that this centre is bilateral, each half controlling, as does each nerve, the corresponding half of the bladder; and that each half is connected by commissural fibres, so that under

ordinary circumstances the two halves act in harmony with one another, and are influenced equally by stimuli transmitted to one or the other. The respiratory centre is just of such a nature. This view I have not yet subjected to experimental verification, but I hope soon to do so.

This centre, be it bilateral or not, is capable of being influenced by nerves other than those which proceed from the bladder. A familiar illustration is found in the case where the external genitals of male infants are either exposed to cold, to heat or handled, when the bladder contracts and expels its contents in the usual way. No doubt the centre may be similarly affected by the stimulation of other sensory nerves. The full action, however, of this centre I do not at present propose to discuss.

The mechanism of micturition in the newly-born infant may be thus summed up.

When the bladder is distended to its accustomed size, an afferent impulse passes along the pelvic splanchnic nerves to the lumbo-sacral enlargement of the spinal cord, the seat of the centre controlling the movements of the bladder, whence it is reflected along the same nerves to the muscular wall of the bladder. Contraction of the bladder is immediately induced, and in consequence the intra-vesical pressure is raised until it overcomes the resistance offered by the urethra. When the urine is forced along the urethra the muscular walls of that tube yield, I presume, in much the same regulated manner as the triceps muscle does in flexion of the elbow-joint.

As the infant grows and becomes conscious of the desire to make water, it soon acquires the power of inducing voluntary contraction of the striped muscle of the urethra, which, coming to the aid of the muscular fibres at the urethro-vesical orifice, effectually checks any flow of urine into and along it. At first this is an effort of will, but after a time it becomes a reflex, and is one of the many acquired reflexes. There arises here an interesting question, namely, how does the child, say of a year old, become conscious of the desire to make water? Is it by contraction of the muscular walls of the bladder setting up an afferent impulse along the pelvic splanchnic nerves, or is it by stimulation of the urethral nerves (internal pudic) caused by

the escape from the bladder into the urethra of a few drops of urine? It seems more than probable that the consciousness results from the sensation of discomfort in the urinary bladder, caused by contractions, perhaps irregular, and therefore ineffectual, of the muscular fibres; and it may be questioned whether any escape of urine into the urethra takes place until the act of micturition has fairly begun.

It is, indeed, a matter of common experience that we possess the voluntary power of checking, at a moment's notice, the flow of urine into and along the urethra, and this is done by contracting the striped muscle of the urethra, including the external sphincter of Henle, the constrictor urethræ, and the accelerator urinæ, all of which are supplied by the pudic nerve. I would again note that when it is desired to check the flow of urine which is running freely, contraction of the urethral muscles alone does not take place, for the sphincter ani and levator ani also contract. In fact, a wave of contraction takes place, starting at the fibres at the urethro-vesical orifice, and calling into action, perhaps by sympathy, the muscular sphincter ani, and ending in the accelerator urinæ. By an effort of will it is very difficult, if not impossible, to cause contraction of any one of this group of muscles alone, all being in the habit of contracting in a regular sequence; and if we desire the constrictor urethræ to contract, the whole series is involuntarily set in motion.

Thus, after a little training, the infant can control the escape of urine; and this power being so often called into use, the function is after a time delegated to a centre in the spinal cord. In short, it becomes an acquired reflex, resisting the contractions of the bladder, just as do other actions which are at first produced only by an effort of will. Soon the bladder contractions cease, and more accumulation of urine is permitted. The bladder will, however, again, sooner or later, contract; and if it is inconvenient to pass urine, the same urethral reflex will be again set up to prevent any escape. This spontaneous urethral contraction, followed by relaxation of the bladder-walls, may be repeated several times. We may also set the same muscles voluntarily into action; and especially is this necessary when the reflex becomes more or less exhausted, especially if the bladder be irritable, and determined, as it were, to expel its contents.

We see, therefore, that in the CHILD there is, in addition to the *spontaneous* reflex, an acquired reflex, in which the striped muscles of the urethra are concerned. The pelvic splanchnic nerve may act as the afferent nerve, as indeed may the pudic; whereas the latter nerve alone is the nerve that conveys a motor impulse to the pelvic group of striped muscles.

A reference to the scheme (fig. 3) will show these two reflex arcs. In the spinal cord a bilateral centre, shaded in the figure, and connected by transverse commissural fibres, is represented, each half of which is connected above with the pelvic splanchnic (P.S.N.), and below with the internal pudic nerve (I.P.N.); and each nerve contains both afferent (sensory) and efferent (motor) nerve fibres, the direction in which impulses travel in each being indicated by arrows. The pelvic splanchnic is connected with the bladder only, and it is concerned with the *spontaneous* reflex; whereas the pudic is connected with the urethra and its striped muscles, and concerned with the *acquired* reflex. The closure of the urethra is also under the control of the will, for the urethra may at any time be constricted by contraction of the striped muscle around it.

In the adult the act of micturition is the same as it is in the older child. In the adult, however, the acquired reflex becomes so perfect, that if the least drop of urine finds its way into the urethra, or indeed if the sensation of muscular contraction in the bladder arise, the striped muscles of the urethra are at once set in action, and the urethral canal thereby effectually closed.

In the adult, therefore, the urine is retained in the bladder for the accustomed period, namely, three to four hours, or until some association of ideas, such as that which accompanies washing the hands, occurs.

Reflex contractions of the bladder from the skin area of the internal pudic nerve, or from that of any other sensory nerve, are not so readily set up in the adult as in the child, except under abnormal conditions of the central nervous system, of which I do not propose to speak here.

There is then in the adult the *spontaneous* reflex, as seen in the newly-born infant, and it is this which determines when the bladder shall contract and endeavour to expel its contents. But there is in the adult, just as in the child, a second reflex

(*acquired*), which determines when the urine shall escape. This reflex may be affected either from the urethra by the stimulation

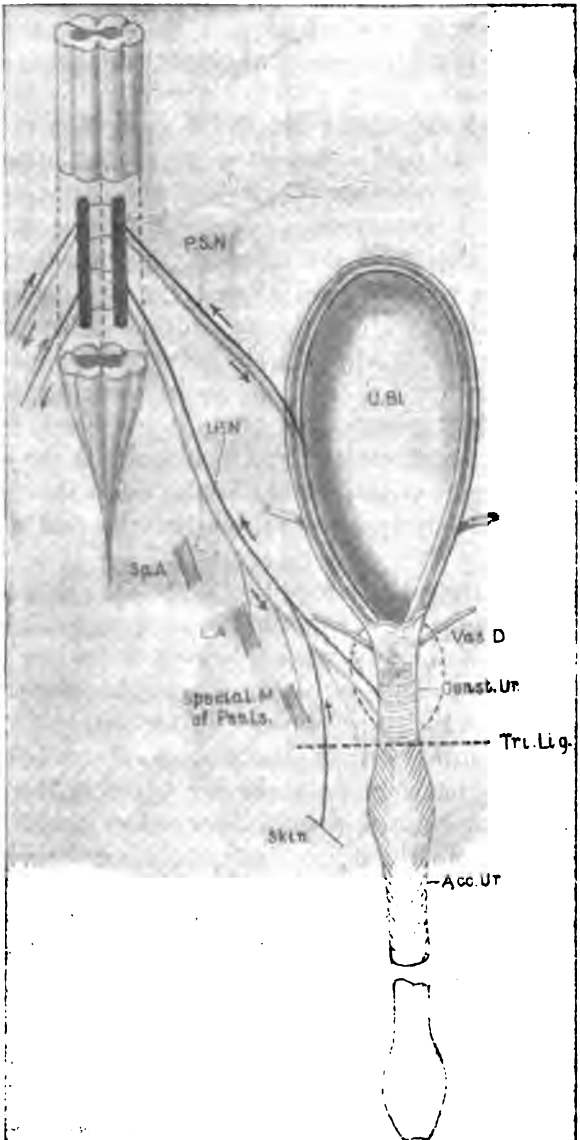


FIG. 3.—(For explanation of this figure, see next page.)

of the terminal ends of the branches of the internal pudic nerve or from the bladder, the stimulus being set up by the contraction of the muscle-fibres of the bladder itself. We have also the power of setting the striped muscle of the urethra into action by an effort of will, but, so far as I can gather, we possess no power, either reflexly or voluntarily, of actually relaxing or, as it were, letting go that muscle. It is, I believe, only by recognising that in the act of micturition we are dealing with two separate actions that this really complex process can be intelligently studied; and I hope to show in a subsequent paper that the various abnormalities of this function can in this way be rationally explained.

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EXPLANATION OF FIGURE 3.

A schematic representation of the bladder and urethra, with their nerves, connected with a hypothetical bilateral centre in the lumbar part of the spinal cord. Each nerve is represented by black lines—afferent fibres, and by dim lines—efferent fibres; and each nerve, pelvic splanchnic, and internal pudic is connected directly with the corresponding half of the centre, and indirectly with opposite half by connecting fibres.

U.Bl.	Urinary bladder.
Ur.	Ureter.
Vas D.	Vas deferens.
Const. Ur.	Constrictor urethræ muscle.
Acc. Ur.	Accelerator urinæ muscle.
Tri. Lig.	Triangular ligament.
Sp. Cord.	Spinal cord.
Mict. Cent.	Centre for control of movements of bladder and urethra.
P.S.N.	Pelvic splanchnic nerve (Nervus erigens).
I.P.N.	Internal pudic nerve.
Sp.A.	Sphincter ani muscle.
L.A.	Levator ani muscle.

THE CENTRAL NERVOUS SYSTEM OF AN ANENCEPHALOUS FŒTUS. By WM. BULLOCH, M.D. [*From the Neuropathological Laboratory, King's College, London.*][1]

THE condition of the central nervous system in microcephaly[2] and hemicephaly[3] has been frequently described, but the literature on anencephaly is meagre; hence the present case may be of interest, especially as it differs considerably from that minutely recorded by Leonowa.[4] In that case, part of the medulla oblongata remained. The spinal cord was small, but its grey matter was fairly well formed, with the exception of Clarke's cell column and the lateral horn of the dorsal region which were absent. The antero-lateral white columns were so small that the grey matter extended to the periphery of the cord. The posterior columns were slightly affected, and Lissauer's boundary zone was totally absent. At the upper end of the cord, the fibres of the posterior columns passed directly across the raphé to form the interolivary layer, without first entering the posterior nuclei of the medulla. The pyramidal and direct cerebellar tracts were absent. The nervus accessorius Willisii was present, and the hypoglossal nucleus contained multipolar ganglion cells.

The case about to be described is that of a *true* anencephalous fœtus. It was sent to King's College for examination, but as no history accompanied it, I am unable to state exactly how old it was. From the condition of its epiphyses, and notwithstanding its small size, it was probably in the ninth month of intra-uterine existence. It weighed 1360 grm., and measured 39 cm. in length, and 28·5 cm. round the shoulders. After hardening in Müller's fluid, the entire spinal cord measured 11 cm. in length. The roof of the cranium was absent, and the exposed basis cranii was covered by a thick, red, semi-gelatinous membrane (substantia medullo-vasculosa of Recklinghausen). The cerebrum, cerebellum, and bulb were completely absent. The foramen magnum was well formed, and was partly occupied by the upper

[1] I desire to express my best thanks to Professor Ferrier and to Dr W. Aldren Turner for their assistance.

[2] Steinlechner—*Gretschischnikoff. Archiv. f. Psych.*, 1886, p. 649.

[3] Schürhoff—*Bibliotheka medica*, 1894, c. hf. 3.

[4] Leonowa—*Archiv. f. Anat. und Phys. Anat. Abt.*, 1890, p. 403.

end of the spinal cord, the dura mater of which was continuous with the above described membrane. In the upper cervical region the spinal cord was deeply cleft posteriorly. The cervical and lumbar enlargements were distinct. The anterior and posterior spinal roots, the posterior root ganglia, and the peripheral nervous system were all found, on dissection, to be normal. The eyes were well formed, but the optic nerves were mere stumps. The bony roof of the orbits was absent, and there was complete *gnathopalatoschisis.* Well formed ossific centres were present in the lower femoral epiphyses.

After hardening in Müller's fluid, the spinal cord with its roots and ganglia was embedded in celloidin, and the sections made were stained by the Weigert-Pal hæmatoxylin method. For the ganglion cells, carmine, nigrosin, and aniline blue were used as stains.

SACRAL REGION OF SPINAL CORD.—*Grey Matter.*

The medullated columns almost completely surrounded the normally formed grey matter. (See fig. 1.)

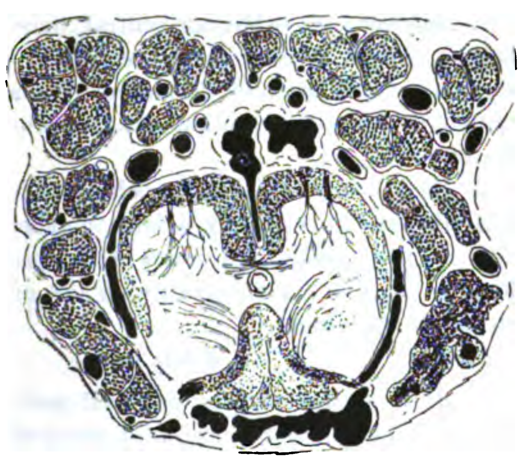


Fig. 1.

1. *Anterior horns.*—Both the latero-dorsal and median cell groups, containing normal multipolar ganglion cells, were seen. The anterior roots entered in two or three well-defined medullated bundles. The remaining medullated network was more loosely arranged than normal. The anterior commissure was normal.

2. *Posterior horns.*—Small rounded ganglion cells were present. With the exception of a bundle of longitudinal fibres, and fibres passing from the posterior columns, no medullated fibres were

observed in the horn. The posterior roots were fully medullated, but few fine fibres were seen. There were no medullated fibres in the posterior commissure.

White matter.

1. *Antero-lateral columns* were medullated with the exception of a small triangular area near the point of entry of the posterior roots, and ventral to the position of Lissauer's boundary zone.

2. *Posterior columns.*—No medullated fibres were seen in Lissauer's zone. In Burdach's column the medullation was such that Flechsig's embryonic "root zones" (anterior, middle, and posterior) were plainly recognised. The "anterior root zone" was the most deeply stained, with the exception of that part immediately adjacent to the posterior median septum. The "posterior root zone" was next deepest stained, and was sharply demarcated from the "middle root zone" ventrally, and the column of Goll mesially. The column of Goll presented a condition of micromyelia.

LUMBAR REGION.—*Grey matter.*

1. *Anterior horn.*—Median, central, dorso-lateral, and ventro-lateral groups of cells were seen at this level. The intra-cornual network was well-developed. The anterior roots entered in four or five large bundles, and the anterior commissure was normal.

2. *Posterior horn.*—Ganglion cells were numerous. The horn was likewise traversed by a large number of fibres from the anterior and middle root zones of the posterior column. The longitudinal fibres of the horn were also medullated. The zona spongiosa was absent.

White matter.

1. *Antero-lateral columns* were well medullated except posteriorly. The medullary sheaths of many of the fibres, however, seemed unusually small in size.

2. *Posterior columns.*—Lissauer's boundary zone was absent. The anterior and middle "root zones" were less distinct than in the sacral region, although more deeply stained than the "posterior root zone" (fig. 2). The column of Goll was very faintly stained by hæmatoxylin, and its fibres appeared small.

DORSAL REGION.—*Grey matter.*

1. *Anterior horns* were unusually large, and contained normal multipolar ganglion cells. The anterior roots entered the horn in three or four bundles.

The medullary network of the horn was very poorly developed.

2. *Lateral horns.*—Only an indication of these were seen, and no ganglion cells were observed in them.

Fig. 2.

3. *Posterior horns* were much larger than normal, and instead of narrowing towards the periphery of the cord, they widened out so as to occupy a considerable area usually occupied by the pyramidal and direct cerebellar tracts (fig. 3). Few ganglion cells were present, and, save some longitudinally coursing fibres, the horns seemed to be destitute of a medullated network. There was no caput cornu. An indentation on its mesial side (normally occupied by Clarke's column) was seen, but contained only one or two cells in individual sections.

White matter.

1. *Antero-lateral columns* were very small, especially posteriorly. The crossed pyramidal tracts were entirely absent, and the direct cerebellar tracts contained only a few fibres.

2. *Posterior columns* in the lower dorsal region (fig. 3) were large. The "anterior root zone" was deeply stained and appeared sharply demarcated from the other "root zones," which were blended a good deal together. Goll's column was not distinguishable from the "posterior" and "middle root zone." In the upper dorsal region (fig. 4), an elongated quadrilateral cavity partially occupied this region. Its walls were lined with neuroglial tissue, but the cavity itself, which contained some cellular debris, did not communicate with the central canal.

The cavity was situated on each side of the posterior median septum and involved parts of both "anterior" and "middle root

zones." The remaining part of the "anterior root zone" was deeply stained. The "posterior root zone" was not demarcated from the column of Goll.

CERVICAL REGION.—*Grey matter.*

1. *Anterior horns* in the lower cervical region were large (fig. 5) and well formed. The anterior roots were medullated, but the normal medullated network of the horn was almost

Fig. 3.

Fig. 4.

absent. The anterior commissure, the central canal, and part of the horn itself were destroyed by the now enlarged cavity.

In the upper cervical region the anterior horns were large and

Fig. 5.

Fig. 6.

scarcely distinguishable from the now much attenuated antero-lateral columns (fig. 6). A very few ganglion cells were present, and the anterior roots were very small.

2. *Posterior horns* in the lower cervical region were well formed, but contained few fibres. In the upper cervical region there was a definite horn, the posterior part of the cord being undifferentiated into grey and white matter (fig. 6).

White matter.

1. *Antero-lateral columns* in the lower part of the cervical region were small, and the pyramidal and direct cerebellar tracts were absent. Higher up, only a few medullated fibres could be seen at the periphery of the cord, in the site occupied normally by the large antero-lateral columns.

2. *Posterior columns.*—In the lower cervical region a large part was destroyed, more especially the column of Goll. In the highest cervical region they were entirely destroyed. The cavity which had begun small in the dorsal region, increased in size at higher levels of the cord, opening posteriorly by a wide orifice, and extending anteriorly to the ventral surface of the cord. Its neuroglial layer was continuous with the membranes of the cord and with the substantia vasculosa, which was composed of dense fibrous tissue bundles, holding in their meshes numerous blood corpuscles. No nervous elements were detected in the membrane.

SUMMARY.

From the above description it can be seen that, although the cord as a whole was well formed, the white matter was small in proportion to the grey. The anterior horn contained normal multipolar ganglion cells. Clarke's column contained very few cells, and the lateral horn of the dorsal region was quite rudimentary.

The antero-lateral columns throughout were small; the pyramidal, the direct cerebellar tracts, and the tract of Lissauer were absent. Of the posterior columns, the "anterior" and "middle root zones" of Flechsig were for the most part well medullated, while the "posterior root zone" and the column of Goll presented varying degrees of micromyelia.

The small size of the antero-lateral columns was due to the complete absence of the tracts which normally descend in this region from the parts above the medulla. The fibres which remained were probably those connecting different segments of the cord. The incomplete development of the direct cerebellar tract and of Clarke's cell column was probably due to the absence of the cerebellum, which is the termination of the axis cylinders of this tract. The absence of the posterior nuclei of the medulla may in the same way explain the condition of the column of Goll.

THE GROWTH OF BRAIN IN MEN AND MONKEYS, WITH A SHORT CRITICISM OF THE USUAL METHOD OF STATING BRAIN-RATIOS. By ARTHUR KEITH, M.D. (Aberd.), F.R.C.S. (Eng.).[1]

1. *Prefatory.*—It has been recognised for a considerable time that the most profitable manner of treating many human anatomical problems is not to view them as isolated questions, but to regard them along with allied phenomena occurring in the group of animals of which Man is an intimate member—the Catarrhini. For instance, the solution of such a much-vexed question as the signification of the preponderance of the male human brain is forwarded to some extent by ascertaining that the sexual variation in brain-weight is by no means peculiar to the human race, but is common to the whole group of old world Apes—the Catarrhini. Neither is Man peculiar in the remarkable mushroom-like expansion of his brain in the early years of juvenility, for investigation shows that a corresponding and proportionately rapid growth occurs in the brains of his congeners. Comparison shows, also, that although the period of brain-growth in Man is protracted over a longer period than in any other member of the Catarrhine group, yet it is only the culmination of a gradually increasing series. Studying Man as a member of this group, and setting side by side the human and pithecian brains, the mass of the human brain does overshadow that of the others; yet the others show, amongst themselves, variations in size to an almost corresponding degree. From an evolutionary point of view, it is still more interesting to find that, when brains of individuals of any species of ape whatsoever are set side by side, a very considerable degree of variation in size is manifested. This fact countenances the conception that the brain-masses which characterise Catarrhine genera are only individual variations accumulated and cemented by Selection.

2. *The material upon which this paper is based.*—It is now over thirty years since Boyd founded our knowledge of the rate of

[1] Presented to the Anatomical Society, November 1894.

growth of the human body organs by publishing in the *Philosophical Transactions* for 1861 the results of 2614 post-mortem examinations of individuals belonging to every decade of life—a Herculean task. Unfortunately his observations dealing with the first two decades of life are comparatively scanty; and owing to his results being given in averages, it is impossible to add the lesser contributions of Bischoff and Parrot. Boyd gives the brain-weights of 250 human males under the age of twenty, and these statistics are here used for the comparison of the human and pithecian brain-growths. Even dealing with 250 individuals, Boyd has been unable to eliminate the error due to the great amount of individual variation, for his tables show the human brain-mass to be larger at seventeen than at twenty-five. Since it is possible to adduce observations on the brain-weights of only some 135 Catarrhine apes, and these belonging to various genera, as is set forth in Table I., it will be at once evident, that although the facts now collected together may form a nucleus for the extension of our knowledge of this subject, the interpretation put upon these facts cannot be more than a rough approximation to the truth.

3. *The addition that has been made to the weight of brains that are weighed after immersion in alcohol.*—Brains that are preserved in saline solutions gain in weight; those kept in alcohol lose in weight. Bischoff estimated the loss due to alcoholic immersion at 25 per cent., Broca at 30 per cent. Both appear to have under-estimated it. Marshall, as well as Symington, found that a chimpanzee brain lost 35 per cent. of its original weight in the course of a few months; while Milne-Edwards observed that the brain of an orang, which originally weighed 400 grms., lost 180 grms.—over 40 per cent.—in the course of two months' immersion in alcohol. In a brain that had been kept in alcohol for over one year, I observed a depreciation of very nearly 50 per cent. The amount lost depends on the strength of spirit and period of immersion; but to a brain that has been for even a week in alcohol, an addition of, at any rate, 33 per cent. of its original weight should be made.

4. *The relationship between cranial capacity and brain-weight.*—Owing to the paucity of observations on the brains of adult anthropoids, one is compelled to utilise their cranial capacities

as a basis from which to calculate their brain-weights. It has been shown that in Man the brain-weight stated in grammes is, *on an average*, equal to about 87 per cent. of the cranial capacity stated in cubic centimetres. (See the writings of Bernard Davis, Bastian, Bischoff, Weisbach, and Manouvrier.) This is true, on an average; but, as Bischoff has shown, in some men the brain-mass is equal to only 78 per cent. of the cranial capacity, while in others it may be equivalent to 98 per cent. The smaller the head, the younger the child, the nearer does the brain-mass approach the cranial capacity; and the curious fact is evidenced in the anthropoids, that the brain-weight stated in grammes exceeds the cranial capacity expressed in cubic centimetres. Symington found that the cranial capacity of a female chimpanzee measured 360 c.c., while its brain weighed 368 grms. This observation is independently substantiated by Milne-Edwards recording in the *Comptes Rendus l'Academie des Sciences* for this year that he found the brain of a male orang to weigh 400 grms., while its cranial capacity amounted to only 385 c.c. The matter certainly requires further investigation, but in the meantime there is no great risk of error in using the cranial capacities of anthropoids as directly indicatory of their brain-weights.

5. *The observations on the brain-weights of the Gibbons, Macaques, and Semnopithecques* have the advantage of being made on animals obtained and examined in the jungle. These animals were in a robust state of health, with, as is natural in their wild condition, almost no fat in their bodies, quite unlike the emaciated or bloated animals that die in captivity. The arachnoid was removed before the brain was weighed; and the stomach contents, which in the Semnopithecque may amount to 4 lbs.—one-third of the entire animal—were deducted in order to obtain the true body-weight.

6. *The length of the period of brain-growth.*—Our present knowledge of the rate of brain-growth in the several members of the Catarrhini is set forth, graphically, in diagrams I.–VIII. In these diagrams the intra-uterine period is represented by three verticals, the first year of life by four, while each succeeding vertical marks a year. The adult brain being counted equal to one hundred, each horizontal marks ten parts. With each

diagram is given the average brain-weight of the adult male, so that both the relative and absolute rate of increase are obtained at a glance.

The brain's course towards maturity shows marked differences in the rate of growth during the *fœtal*, the *infantile*, and the *adolescent* periods of life. Of the fœtal period we know little; in the infantile stage there is an extraordinary rapidity of growth; in adolescence there is a slow, gradual increase, running *pari passu* with the growth of body. With an increase of one period there is an increase of the other; so that when the cat's brief span of brain-growth is set down side by side, as in diagrams IX.–X., with man's protracted period, both being drawn to the same scale, the curves representing the brain-growth are observed to resemble each other closely, save that there is a considerable difference in the rapidity of growth during the infantile period. The course of brain-growth in the cat is relatively identical with that of Man, but is packed in a shorter space of time. So also with the various members of the Catarrhine group: the relative rate of increase is almost the same in all, but in the lower forms the period of maturation occupies five, six, or seven years, while in the higher forms it extends over fifteen to perhaps twenty-five years. The most marked hiatus is observed to occur between diagrams IV. and V., representing the orang and gibbon, and between these two also occurs the greatest interruption in the series of body-weights. With an increase in mass of body occurs a prolongation of all the stages of brain-growth, so that mass of body, perhaps also mass of brain and periods of brain-growth, appear to be closely related. But it will be observed that although the mass of man's body is less than that of the gorilla, yet his period of brain-growth is more prolonged. There is reason, however, to doubt that the human brain does increase until twenty-five, for an examination of European statistics dealing with this matter is not at all convincing; and such data as are available from the measurements of heads, as those of Galton on Cambridge students, are unsatisfactory, for it is impossible to allow a proper amount for the increase due to osseous growth in the frontal and occipital regions of the skull.

Another singular point brought out by these diagrams is, that

as one ascends the animal scale, the infantile brain becomes smaller and smaller in proportion to that of the adult. For instance, in the second month of life a cat possesses 90 per cent. of its entire brain, a macaque over 70 per cent., a gibbon under 70 per cent., while a human baby, at a similar period of life, has only obtained 36 per cent. of the adult brain. Of all animals, the human baby at birth has relatively, if not absolutely, the greatest quantity of brain-matter to acquire before maturity is attained; but in this respect also Man represents only the climax of a graduating series. (See diagrams I.–VIII.)

In this connection it is interesting to note, that while the brain of the human baby in the second month equals in mass that of the adult gorilla, the brain of a corresponding gorilla much exceeds in mass that of an adult siamang. Further on we shall show what relationship this fact bears to the brain-powers of these animals.

7. *The rate of brain- and body-growth compared.*—In the initial stages of life, the rapid growth of brain which is characteristically seen in this group of animals, stands in marked contrast to the more or less gradual and proportionate growth of the other body-organs (diags. IX.–X.). In Man and the higher anthropoids, while the body-organs have attained by the fifth year only a small proportion of their mature size, the brain has reached nearly 90 per cent. of its complete development. In the lower forms the disproportion in the growth of the brain and other body-organs is even greater than in the higher forms. But both the brain and body organs agree in this, that both respond in growth according to the demands of physiological necessity. The kidney gradually rises to meet its increasing function, and it is surely advantageous that an animal should at an early stage be presented with the organ that is to guide and preserve it, that is to interpret for it, and correlate it with its surroundings. This early brain-expansion, which, as has been pointed out, is most marked in the lower animals, may be taken as an indication of their mental precocity, while the more gradual infantile growth in the higher forms may be regarded as significant of their early mental helplessness.

8. *A comparison of the rates of growth of the cerebrum, cerebellum, spinal cord, and body.*—In diagram IX. for Man, and X.

for the cat, curves represent the relative rates of growth of the body and nerve centres. Line *a*, which indicates the body-growth, pursues, with some rhythmical variations, a fairly steady course towards maturity; but the lines *b*, *c*, and *d*, which represent the increase of the nerve centres, describe rocket-like springs in the infantile period. In that period the growth of the nerve centres is relatively much greater than that of the body, and the higher the centre the greater is the disproportion,—that is to say, the spinal cord, in the infantile period of growth, responds to the increase of body to a considerable degree, the cerebellum to a small degree, the cerebrum to a very small degree. But during the period of juvenility, all the nerve centres appear to respond directly to an increase of body-mass; the lower the centre the greater the response (diags. IX.–X.). Research will probably show that the lower the animal in the scale of vertebrate life, the nearer does the rate of growth of all the nerve centres correspond with the rate of growth of the rest of the body.

9. *The amount of corporeal concomitant in the brain.*—It has long been recognised that mass of body, to a large extent, influences mass of brain. That part of the brain which is present by virtue of the mass of body may be designated the "corporeal concomitant." It is highly important to recognise the presence of this element in the brain, for many facts indicate that it does not serve as a substratum for any of the higher mental faculties. Only on such a supposition can one understand the comparatively low intelligence manifested by such massive brains as those of the elephant and whale. The Newfoundland possesses a brain 23 grms. heavier than that of the sheep-dog, but no one will be prepared to assert that this increase of brain-tissue brings with it a corresponding increase of intelligence. In fact, in this case, the difference in brain-weights seems to depend entirely upon the difference of body-weights, and the 23 grms. of brain-excess in the Newfoundland is the corporeal concomitant of the 16,000 grms. excess of body-weight. Apparently it requires an addition of 23 grms. of brain-matter simply to manipulate an addition of 16,000 grms. body-matter.

Were it not for the profusion of individual variation in the brain-masses of a species, the corporeal concomitant would be

easily determined. The several varieties of dogs, however, which manifest large differences of body-weights, yet within the same variety hold fairly tenaciously to the same size of brain, offer material for an approximate appreciation of the corporeal concomitant. Manouvrier gives the following statistics:—

10 dogs—av. body wt.	7,260 grms.;	av. brain wt.,	68·53 grms.		
10 ,, ,,	14,800 ,,	,,	86·25	incr. per kilo. body wt.	2·5 grms.
9 ,, ,,	23,095 ,,	,,	99·50	,,	1·7 ,,
9 ,, ,,	35,187 ,,	,,	108·17	,,	·7 ,,

—(See diagram XIV.)

Marshall (*Journ. Anat. and Physio.*, 1892, p. 490), quoting from Boyd's tables, gives the following facts for men:—

Men—av. body wt.,	53 kilos.;	av. brain wt.,	1292·5 grms.		
,, ,,	60·3 ,,	,,	1330·2	incr. per kilo. body wt.	4·7 grms.
,, ,,	66·6 ,,	,,	1356	,,	4 ,,
,, ,,	73·4 ,,	,,	1366	,,	1·5 ,,

—(See diagram XIII.)

Broca was of opinion that with each addition of 10 cm. to the human stature there was a corresponding addition of 5 grms. to the brain, while Marshall sets the amount down at 2·4 grms. Stature is an unsatisfactory index of mass of body, even when used for men only; it is entirely inapplicable to animals. It is true that, owing to the extreme susceptibility of the human body to fluctuations from emaciation or deposition of fat, the weight is not a very correct index of the true mass of body; but, for comparative purposes, it is the only method available. From the above figures it is quite evident that there is a corporeal concomitant, and that with each successive kilo. it becomes smaller and smaller in amount, so that the final additions to the body-weight of such massive animals as the whale and elephant must carry with them in the brain a very small corporeal concomitant indeed. The corporeal concomitant is a progressively diminishing amount.

10. *The theory of a corporeal concomitant applied to the interpretation of the curves of brain-growth.*—Applying these facts to the interpretation of the curves of brain-growth represented in diagrams IX.–X., one comes to the conclusion that the greater

part of, or probably all, the brain-growth that occurs in Man after the age of eleven—the period of adolescence—is an addition of corporeal concomitant only. Boyd's tables, from which diagram IX. is compiled, give the increase in body-weight of Man from the eleventh to the twenty-fifth year at about 22 kilos., and the brain-increase in the same period at 60 grms. According to the figures given above, the corporeal concomitant added to the brain during the adolescent period of man's growth is 3·4 grms. per kilo. body-weight; thus one calculates that, for the 22 kilos. added as shown in Boyd's tables, there ought to be an increase of nearly 75 grms. in the body-weight. When one remembers the exceedingly large amount of individual variation both in brain- and body-weights of men, one will be inclined to agree that the brain curve in diagram IX., after the eleventh year, very probably represents an increase in the brain of corporeal concomitant only. The rocket-like rise of the nerve curves during the period of infantility I take to indicate a rapid deposition of nervous tissue which is to serve as substratum for functions required at an early stage of existence, and which entirely masks the coexisting increase due to the corporeal concomitant. How the amount of increase due to the corporeal concomitant during the infantile period of brain-growth can be determined I cannot at present tell; but it appears to be proportionately greater than in the period of adolescence.

It seems highly probable, then, that the later additions to the brains of all animals are not additions to the substrata that subserve the intellectual faculties, but are wholly at the disposal of purely animal and corporeal functions. That there is an increase of brain by reason of an increase of body is undeniable: the amount cannot as yet be satisfactorily determined, but comparative anatomy and psychology indicate that it in no way furthers higher mental operations. If such be the case, each human individual, by the age of twelve, reaches a climax as far as the basis of his intellectual organ is concerned, and the improvement that comes with years comes entirely by way—not of increase of the instrument, but—of increased facility in its application.

11. *A comparison of the brain-masses of the members of the Catarrhini.*—In diagram XI. are set forth, in due proportion, the

average brain- and body-weights of adult males of Man, Gorilla, Chimpanzee, Orang, Siamang, Gibbon, Macaque, and Semnopithecque. The upper columns, each horizontal of which marks 100 grammes, represent the brain-weights; the lower columns, divided by horizontals, each indicating 5000 grammes, depict the corresponding body-weights. The column representing the human brain towers above those of the Anthropoids, and they in turn rise above those of the Cercopithecidæ. But before the columns will in any way indicate the actual amount of mental substrata of these animals, it is necessary to deduct the corporeal concomitant. Undoubtedly, the corporeal concomitant per kilo. is a varying amount in the different species of animals, and there are grounds for stating that, of this group, Man possesses it to the largest degree. Although the amount deducted be only a rough approximation—a guess—to the correct body concomitant, yet, it seems to me, in no other way can the relative brain-endowments be satisfactorily stated. From the above figures the *average* corporeal concomitant in the brain of a man weighing 60 kilos. may be set down at 4 grms. per kilo. The bodies of the adult male anthropoids being greater than that of Man, and their nerves being proportionately smaller, one may set down their corporeal concomitants at about 2·5 grms. per kilo. Arguing from dogs, one may estimate the corporeal concomitant in the smaller Catarrhine forms at 3 grms. per kilo. When these deductions are made, the brain-tissue that does not immediately subserve any corporeal function may be set down in Man as 1120 grms., in the gorilla 235 grms., the chimpanzee 225 grms., the orang 220 grms., the gibbon 82 grms., the macaque 75 grms., and the semnopithecque at 50 grms. (See diagram XII.)

This appears to me to be a method of stating the brain endowment of an animal more rational than that of expressing it in terms of the body-mass. The body-mass would be a fit standard against which to measure the brain-mass, did the higher nerve centres expend all their energy on the body. But seeing that a small part only of the brain exercises itself directly on the body, it is at any rate inaccurate, as a method of stating the degree of brain-mass or power, to turn an animal into a vulgar fraction, placing the total brain-weight as a numera-

tor, the body-weight as a denominator, and by reducing it to a decimal, to obtain a figure which is used to indicate that animal's brain-endowment.

12. *The sexual variation in brain-weight.*—In table I. a list is given of the average weights of the adult male and female brains. In all the genera examined the male brain exceeds that of the female, but only in the macaque does the male excess equal, relatively, that of the human species. The excess is largely due to the preponderance of the male in body-weight, and the residue not thus accounted for is probably also of the nature of corporeal concomitant. That the increase of brain-tissue—the sexual concomitant — subserves a purely bodily function, one may infer from the immense influence that the sexual organs exercise on the body-growth—most probably through the nervous system. Observation is required to show that the nervous centres of castrated animals are lighter than those of entire animals of corresponding weight, but one would expect this to be the case.

13. *The amount of individual variation in brain-weight.*—In table I. the range of variation in the brain-weights of individuals belonging to the same species is stated. The amount of variation, both absolute and relative, increases as one passes from the lower to the higher forms, so that in the Anthropoids there is a greater amount of material upon which selection may act than among the Cercopithecidæ.

There is, in this paper, no attempt whatsoever made to reach finality as to the relationship of the body to the nerve centres, or of the one centre to the other in this interesting group of animals. The data given are both meagre and imperfect; but as there is no possibility at present of extending my observations, it appears best to publish them, with the hope that they may lead to the accumulation of more.

[TABLES.

Table I.

[Readers are requested to notice that the Tables are not in consecutive order.]

A Table giving a Summary of the Animals examined as to their Brain-Weights.

	Number of adults examined. ♂.	Average brain-weight.	Fluctuation in weight of brain (maximum and minimum).	Number of adults examined. ♀.	Average brain-weights.	Fluctuation in weight of brain (maximum and minimum).	Sexual difference.	Average body-weight. ♂.	Average body-weight. ♀.	Total number of animals of all ages examined.
Gorilla	12	463	387–565	6	450	393–496	13	90·000	?	38
Chimpanzee	2	406	360–452	4	393	360–425	13	80·000(?)	?	29
Orang	3	431	400–470	1	393	...	?	80·000	?	11
Siamang	1	130	...	...	...	...	...	9·500	...	4
Gibbon	2	101	99–103	5	92	78–96	9	5·250	5·780	13
Macacus	3	97·7	93–103	4	81·5	78–88	16	7·280	4·47	18
Semnopithecus	3	67·8	62–76	7	62·8	56–72	5	6·540	5·040	17
Miscellaneous monkeys	...	...	...	...	...	...	...	...	...	5

The weights are expressed in grammes. Total, 135.

Table II.

A Table of Gorilla Brain-weights.

	Sex.	Age.	Body-weight.	Brain-weight.	Observer.
1. Gorilla	♂	Adult	90·720 kilos.	426·25 grms.	Owen.*
2. ,,	♂	,,	...	†387· ,,	Broca.
3. ,,	...	Young	...	†230· ,,	Chapman.
4. ,,	♂	Possessed milk teeth only	...	†331·25 ,,	Bischoff.
5. ,,	...	2 or 3 years	6·711 kilos.	416 ,,	Manouvrier.
6. ,,	♀	Foetus 5th or 6th month	500 grams.	Cranial capacity 32 cubic centimetres. Calculated brain-weight 30 grams.	

* See table of references.

† Weight calculated after the brain had been immersed in alcohol.

TABLE III.

A Table of Gorilla Cranial-capacities.

	Sex.	Age.	Cranial Capacity.	Observer.
1. Gorilla	...	Milk teeth not completely present	355· c.c.	Virchow.
2. ,,	...	Milk teeth cutting	415· ,,	Török.
3. ,,	♀	Young	377·4 ,,	Turner.
4. ,,	...	Complete set of milk teeth	500· ,,	Török.
5. ,,	...	,, ,,	380· ,,	Bischoff.
6. ,,	♀	,, ,,	380· ,,	Virchow.
7. ,,	...	,, ,,	410· ,,	,,
8. ,,	...	,, ,,	425· ,,	Bischoff.
9. ,,	...	,, ,,	450· ,,	,,
10. ,,	♀	Adult	350· ,,	,,
11. ,,	♀	Milk teeth falling out	335·79 ,,	Wyman.*
12. ,,	♀	Adult	393· ,,	,, *
13. ,,	♀	,,	409·62 ,,	,,
14. ,,	♂	,,	425·88 ,,	,,
15. ,,	♀	,,	434·2 ,,	Turner.
16. ,,	♂	,,	442·26 ,,	Kneeland.
17. ,,	♂	,,	458·78 ,,	Turner.
18. ,,	♂	,,	458·8 ,,	Wyman.*
19. ,,	♂	,,	465· ,,	Bischoff.
20. ,,	♂	,,	463·7 ,,	Wyman.*
21. ,,	♂	,,	475·00 ,,	,,
22. ,,	♀	,,	483·20 ,,	,,
23. ,,	♀	,,	484·82 ,,	,,
24. ,,	♀	,,	496·46 ,,	,,
25. ,,	♂	,,	500· ,,	Duvernoy.
26. ,,	♂	,,	534· ,,	Wyman.*
27. ,,	...	,,	520· ,,	Duvernoy.
28. ,,	...	,,	550· ,,	Broca.
29. ,,	...	,,	560· ,,	Meyer.
30. ,,	...	,,	570· ,,	Manouvrier.
31. ,,	♂	,,	565· ,,	Wyman.*
32. ,,	...	,,	573· ,,	Huxley.

* See reference 7.

TABLE VI.

Table of Orang Brain-weights.

	Sex.	Age.	Body-weight.	Brain-weight.	Observer.
1. Orang-outang	♀	Complete set of milk-teeth	3·170 kilos	248· grms.	A. Keith.
2. ,,	♂	1st perm. molar in use	7·600 ,,	340·2 ,,	Rolleston.
3. ,,	♂	Young	7·500 ,,	365· ,,	Manouvrier.
4. ,,	...	1st perm. molar cutting	60 ctm. (crown to sole)	320· ,,	Bischoff.
5. ,,	♂	3 years	...	283·5 ,, *	Chapman.
6. ,,	♂	1st perm. molar cutting (4½ years in captivity)	18·600 kilos	325·1 ,,	Owen.
7. ,,	♂	Adult	73·500 ,,	400· ,, *	Milne-Edwards.

* Cranial capacity of this animal was 385 c.c.

Table IV.

Table of Chimpanzee Brain-weights.

	Sex.	Age.	Body-weight.	Brain-weight.	Observer.
1. Chimpanzee	♀	2nd and 3rd perm. molars uncut	½ grown	311·85 gr.	Traill.
2. ,,	♂	1½ or 2 years	7·43 kilos	379·03 ,,	Embleton.
3. ,,	♂	...	66 ctm. in height (crown to sole)	324·04 ,,	Tyson.
4. ,,	♂	Very young	...	276·3 ,,	Owen.
5. ,,	♀	Canines and 3rd perm. molar teeth, uncut	19·290 kilos	375·63 ,,	,,
6. ,,	♂	1st perm. molars appearing	7·454 ,,	396·9 ,,	Marshall.
7. ,,	♀	5 years	71 ctm. in height (crown to sole)	285·4 ,,	Chapman.
8. ,,	♂	4 ,,	9·000 kilos	381·0 ,,	Bischoff.
9. ,,	♀	10 years. Canine 2nd and 3rd perm. molars still uncut	...	*368·0 ,,	Beddard.
10. ,,	♀	5 years	...	*264·0 ,,	,,
11. ,,	♀	,,	...	*290·0 ,,	,,
12. ,,	♀	1st perm. molar cut	65·2 ctm. (crown to sole)	368·5 ,,	Symington.
13. ,,	♂	Complete set of milk-teeth	72 ctm.	304·0 ,,	Muller.
14. ,,	...	...	...	269·3 ,,	Parker.†
15. ,,	...	...	...	311·8 ,,	Drell.†
16. ,,	♀	2 years	...	310·0 ,,	Giacomini.
17. ,,	...	...	...	389·86 ,,	Spitzka.†

* Brain-weights calculated after immersion in alcohol.
† See reference 19.

Table V.

Table of Chimpanzee Cranial Capacities.

	Sex.	Age.	Cranial Capacity.	Observer.
1. Chimpanzee	...	Complete set of milk-teeth	327·6 c.c.	Owen.
2. ,,	♀	Young	344· ,,	Turner.
3. ,,	...	...	262· ,,	Du Chaillu.
4. ,,	...	...	311· ,,	,,
5. ,,	...	...	360· ,,	,,
6. ,,	...	...	409· ,,	,,
7. ,,	♂	Adult	360· ,,	Turner.
8. ,,	♀	,,	393· ,,	,,
9. ,,	♀	,,	360· ,,	Owen.
10. ,,	♀	,,	393· ,,	,,
11. ,,	♀	,,	425·8 ,,	,,
12. ,,	♂	,,	452· ,,	,,

TABLE VII.

Table of Orang Cranial Capacity.

	Sex.	Age.	Cranial Capacity.	Observer.
1. Orang-Outang	...	Set of milk-teeth complete	288·5 c.c.	Owen.
2. ,,	♀	Adult	395·0 ,,	,,
3. ,,	♂	,,	425·8 ,,	,,
4. ,,	♂	,,	470·0 ,,	Milne-Edwards.

TABLE IX.

Table of Macaque Brain-weights.

	Sex.	Age.	Body-weight.	Brain-weight.	Observer.
1. Macacus nemestrinus	♂	Adult	7·700 kilos.	103·1 grms.	A. Keith.
2. ,,	♂	,,	7·600 ,,	92·8 ,,	,,
3. ,,	♂	Canine teeth developed, but animal less matured than the above	6·540 ,,	97·4 ,,	,,
4. ,,	♀	Pregnant	5·100 ,,	79·00 ,,	,,
5. ,,	♀	Adult	4·500 ,,	78·4 ,,	,,
6. ,,	♀	Canines not yet developed	4·100 ,,	88·2 ,,	,,
7. ,,	♀	Carrying child at breast	4·080 ,,	*80·6 ,,	,,
8. ,,	♂	Canines and 3rd molars uncut	3·100 ,,	87·6 ,,	,,
9. ,,	♂	Adult	5·200 ,,	80·00 ,,	,,
10. ,,	♀	Set of milk-teeth complete	·610 ,,	67·50 ,,	,,
11. ,,	♀	1st perm. molar cutting	1·020 ,,	85· ,,	,,
12. ,,	♂	Central incisors cut; lateral, cutting	·385 ,,	†70·1 ,,	,,
13. ,,	♂	Fœtus (about fifth month of intra-uterine life) (7·6 ctm. crown to sole)	·785 ,,	‡8·00 ,,	,,
14. Macacus cynomolgus	♂	1st perm. molar cut, 2nd cutting	1·930 ,,	74·7 ,,	,,
15. ,,	♂	Young	1·765 ,,	63·0 ,,	Manouvrier.
16. ,,	♂	Adult	7·080 ,,	80·5 ,,	A. Keith.
17. Macacus arctoides	♂	1st perm. molars cutting	2·154 ,,	102·05 ,,	,,
18. Macacus niger	♀	Very much emaciated by having been kept in confinement. Three months old	·263 ,,	50·00 ,,	,,

* Spinal cord 11·3 grms. † Spinal cord 1·7 grms. ‡ Spinal cord 1·1 grms.

TABLE VIII.

Table of Gibbon Brain-weights.

	Sex.	Age.	Body-weight.	Brain-weight.	Observer.
1. Hylobates lar.	♂	Fœtus (corresponds to a human fœtus in the fifth month)	56·5 grms.	13· grms.	A. Keith.
2. " "	♂	1st perm. molars cut ; 2nd perm. molars cutting	3·027 kilos.	89·0 "	Kohlbrugge.
3. " "	♀	Adult	7·250 "	96·4 "	A. Keith.
4. " "	♂	"	5·000 "	99·05 "	"
5. " "	♀	"	4·760 "	96·1 "	"
6. " "	♀	"	5·200 "	96·08 "	"
7. Hylobates pileatus	♂	Lateral incisors cutting the gum (at breast, probably about 2-3 months old)	·468 "	67·8 "	"
8. " "	♀	Adult (mother of No. 7)	5·440 "	78·0 "	"
9. " "	♂	Adult	5·500 "	102·98 "	"
10. Hylobates syndactylus	♂	Complete set of milk-teeth	1·250 "	100·00 "	Kohlbrugge.
11. " "	♀	1st perm. molars cut	2·057 "	116·00 "	"
12. " "	♂	Adult	9·500 "	130·00 "	"
13. Hylobates leuciscus	♀	"	6·250 "	94·50 "	"
14. Hylobates cendre	...	Young	1·923 "	103·00 "	Manouvrier.
15. Hylobates syndactylus	...	...	...	*63· "	Waldeyer.
16. Hylobates lar.	...	...	...	*73· "	"
17. Hylobates leuciscus	...	...	...	*70· "	"

* These brains had been for a considerable time in alcohol.

TABLE XI.

Table of Brain-weights of Miscellaneous Monkeys.

	Sex.	Age.	Body-weight.	Brain-weight.	Observer.
Cynocephalus maimon	♀	Young	3·755 kilos.	145· grms.	Manouvrier.
Ateles marginatus	...	...	3·188 "	97· "	"
Mycetes seniculus	♂	Adult	3·440 "	47·6 "	Flower.
Lagothrix Humboltii	...	...	1·957 "	85· "	Manouvrier.
Pithecia monachus	♀	Nearly adult. Much emaciated	·538 "	36·22 "	Flower.

TABLE X.—*Table of Semnopithecque Brain-weights.*

	Sex.	Age.	Body-weight.	Brain-weight.	Observer.
1. Semnopithecus obscurus	♂	Adult	6·120 kilos.	76· grms.	A. Keith.
2. ,,	♂	,,	7·030 ,,	64·7 ,,	,,
3. ,,	♂	,,	6·470 ,,	62·8 ,,	,,
4. ,,	♀	,,	4·530 ,,	72·0 ,,	,,
5. ,,	♀	,,	5·210 ,,	64·4 ,,	,,
6. ,,	♀	,,	5·110 ,,	56·7 ,,	,,
7. ,,	♀	,,	5·280 ,,	57·80 ,,	,,
8. ,,	♀	,,	4·760 ,,	60·5 ,,	,,
9. ,,	♀	,,	4·530 ,,	64·4 ,,	,,
10. ,,	♀	,,	5·900 ,,	*64·3 ,,	,,
11. ,,	♂	Last molar and canine teeth still uncut	3·630 ,,	60·5 ,,	,,
12. ,,	♂	,, ,,	3·230 ,,	64·4 ,,	,,
13. ,,	♂	Complete set of milk teeth	2·730 ,,	62·80 ,,	,,
14. ,,	♀	2nd perm. molars cutting	3·170 ,,	65·00 ,,	,,
15. ,,	♀	1st perm. molar in use	2·520 ,,	57·80 ,,	,,
16. ,,	♀	Newly-born, central incisors cut, lateral cutting	·514 ,,	42·88 ,,	,,
17. ,,	♂	Fœtus (4 ctm. long	5·18 ,,	1·20 ,,	,,

* Spinal cord 10·6 grms.

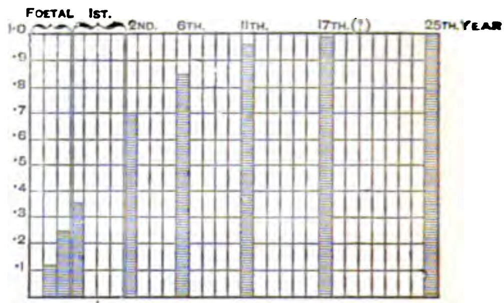
TABLE XII.—*Showing the weight (in grammes) of the various nerve-centres at different ages.*

	Age.	Sex.	Body-weight.	Encephalon.	Cerebrum.	Cerebellum.	Med. ob.	Spinal cord.
1. Cat	Adult	♀	2610 (1·00)	24 (1·00)	16·1 (1·00)	3·5 (1·00)	1·4	8·2 (1·00)
2. ,,	3½ months	♀	1220 (·47)	26·51	17·	3·25 (·93)	1·	5·6 (·68)
3 ,,	2½ ,,	♀	701 (·27)	22·25 (·92)	15·25 (·94)	3·05 (·88)	·8	4·2 (·51)
4. ,,	Neo-nat.	♀	122 (·047)	6·55 (·27)	4·6 (·39)	·54 (·15)	·2	·75 (·09)
1. Bitch (pariah)	Adult	♀	20·300	76·4	64·7	11·4	..	18·7
2. Pup of the above	6 weeks	♂	2·040	38·27	35·6	2·9	..	2·4
1. Macacus nemestrinus	Fœt.	♂	78·5	8·	6·2	1·1	..	..
2. ,, ,,	2 months	♂	·285	70·1	..	..	..	1·7
3. ,, ,,	Adult	♀	4080	80·6	..	..	..	11·4
Orang. (Bischoff)	About 5 yrs.	..	..	320·	275·	with med. oblong. =45	..	..
,, (Milne-Edwards)	Adult	♂	73500·	400·	333·7	with med. oblong. =66·3	..	..
Chimpanzee (Marshall)	About 5 yrs.	♀	7454	396·9	330·56	57·56	8·78	..
1. Man. (Boyd)	Birth	♂	2296 (·05)	330 (·24)	317·5 (·27)	25·5 (·17)	5·6 (·2)	..
2. ,, ,,	During 2nd month	♂	3232 (·077)	493·8 (·36)	458·4 (·39)	30·3 (2)	6·8 (·26)	..
3. ,, ,,	1½ years	♂	5622 (·13)	9420 (·7)	826·6 (·69)	100·3 (·67)	14·07 (·53)	..
4. ,, ,,	5½ ,,	♂	11560 (·27)	1138·5 (·84)	1002·9 (·89)	118· (·79)	17·57 (·74)	..
5. ,, ,,	10½ ,,	♂	19320 (·46)	1301·8 (·95)	1144·2 (·96)	137·2 (·93)	21·54 (·81)	..
6.* ,, ,,	17 ,,	♂	30640 (·73)	1375	1192	150·8	28·35	..
7.* ,, ,,	25 ,,	♂	42080 (1·00)	1361	1197·6	148·	26·36 (100)	..

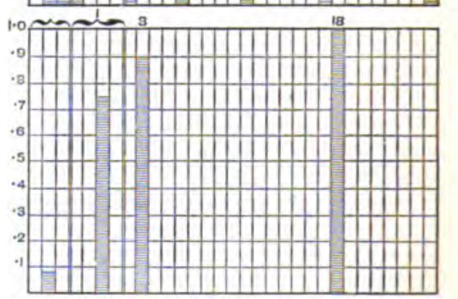
* Of class 6, only 17 individuals were examined; of class 7, 55 individuals

Diagrams of Brain-growth.

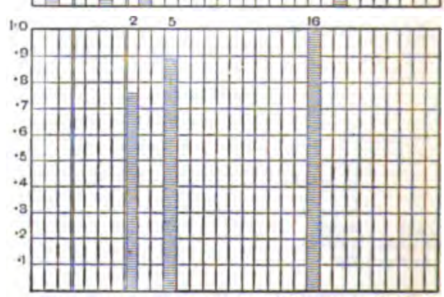
Diag. I.
Man.
Brain of Adult Male — 1360 grms.



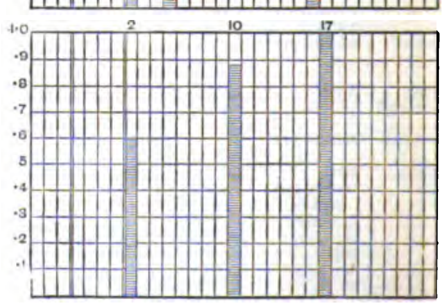
Diag. II.
Gorilla.
Brain of Adult Male — 460 grms.



Diag. III.
Chimpanzee.
Brain of Adult Male — 400 grms.

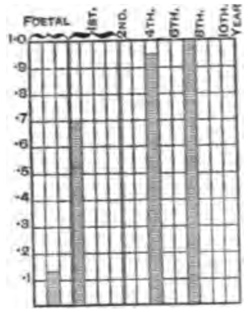


Diag. IV.
Orang.
Brain of Adult Male — 420 grms.

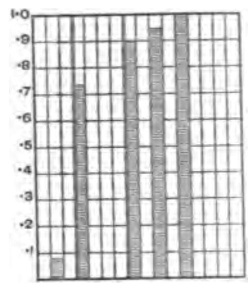


Diagrams of Brain-growth.

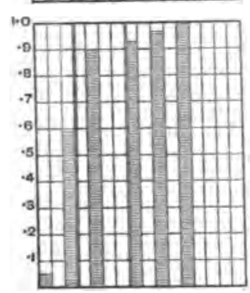
Diag. V.
Hylobates lar.
Brain of Adult Male = 100 grms.



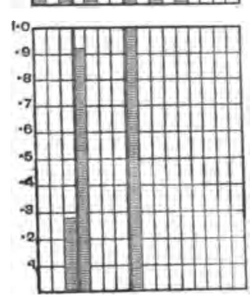
Diag. VI.
Macacus nemestrinus.
Brain of Adult Male = 97 grms.



Diag. VII.
Semnopithecus obscurus.
Brain of Adult Male = 67 grms.

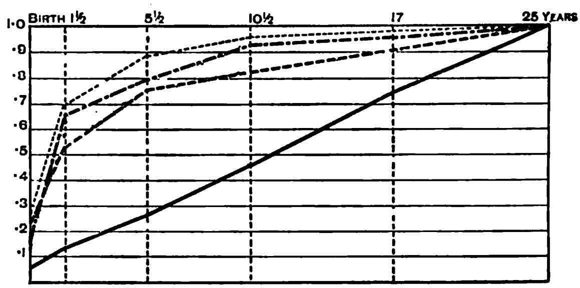


Diag. VIII.
Cat.
Brain of Adult = 24 grms.



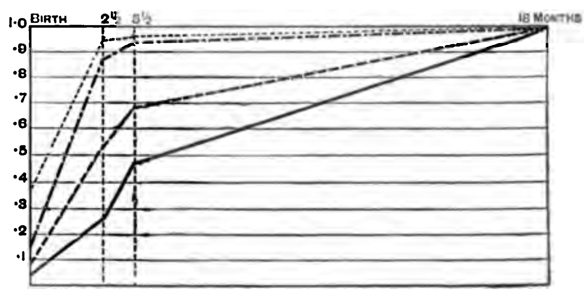
Diagrams showing the relative rate of growth in the Cerebrum, Cerebellum, Medulla Oblongata, Spinal Cord, and Body.

Diag. IX.
Man.



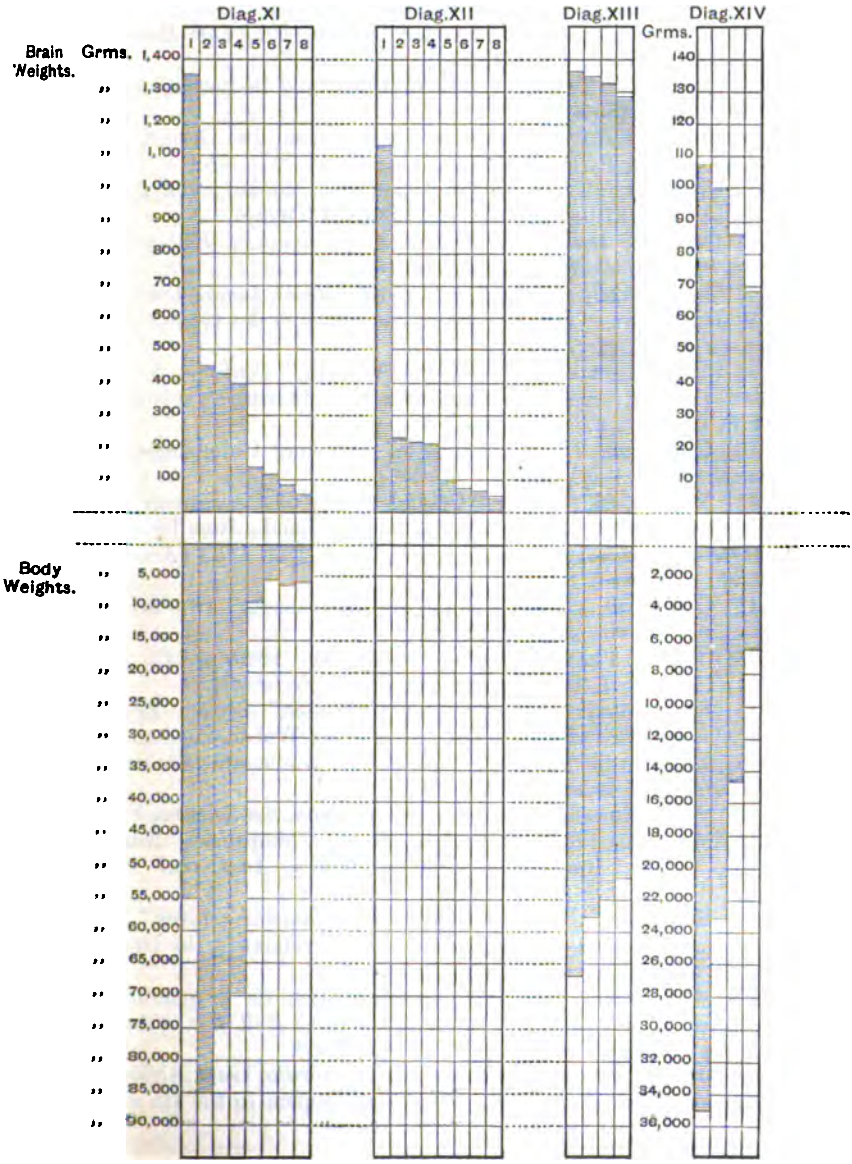
..............Cerebrum.
..............Cerebellum.
..............Medulla oblongata. (*In diag. X.—spinal cord.*)
..............Body. (*The medulla oblongata is an uncertain amount.*)

Diag. X.
Cat.



Diagrams showing Influence of Body-weight on Brain-weight. The upper columns represent the Brain-masses, the lower the Body-masses.

Diag. XI. represents the relative Brain- and Body-weights of (1) Man, (2) Gorilla, (3) Orang, (4) Chimpanzee, (5) Siamang, (6) Gibbon, (7) Macaque, (8) Semnopithecque. Diag. XII. The Brain-masses of the same animals with the Body Concomitants deducted. Diag. XIII. The Brain- and Body-masses in four groups of Men from Boyd's Tables. Diag. XIV. The Brain- and Body-weights of four groups of Dogs, constructed from Manouvrier's data.



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NOTES ON THE MICROCEPHALIC OR IDIOT SKULL, AND ON THE MACROCEPHALIC OR HYDROCEPHALIC SKULL.

By Sir GEORGE HUMPHRY, F.R.S., *Professor of Surgery in the University of Cambridge.*

IT may be interesting to compare these opposite conditions of the skull which depend upon corresponding opposite conditions of the brain. In the one the brain is defective in size, and the dimensions of the cranial cavity are proportionately small. In the other the brain is large, expanded rather by fluid contained in its ventricles, and the cranial parts of the skull are proportionately expanded. The expansion affects all the parts, the vault or least resisting part most, but the base also in some degree, causing an elongation of it, which in some instances is very perceptible in the basi-sphenoid and basi-occipital region, causing also a widening of it, which is evinced by the distance between the glenoid cavities and by the splaying out of the petrosal parts of the temporal bones and of the ridge formed by the lesser alæ of the sphenoid bone.

THE IDIOT OR MICROCEPHALIC SKULL.

The chief features of this form of skull may be briefly stated as follows, from the observation of the nineteen examples of which details are given later on.

The cranial or cerebral part of the skull is small in all its dimensions, particularly in the frontal region which is due in great measure to the slanting backwards of the upper or squamous part of the frontal bone. At the same time that bone is narrow, and its orbital plates are arched and slant somewhat upwards and backwards, deepening and narrowing the ethmoidal fossa. The occipital bone slants upwards and backwards from the foramen magnum; and the obliquity in some includes the hinder or post-condyloid part of the foramen. This, together with the slanting upwards of the basilar part, leaves the condyles

unusually prominent, particularly at their fore part. The hinder or occipital region of the skull is, however, better developed, more expanded, than the anterior or frontal part. This contrasts with the development of the idiot brain, in which, as shown by Professor Cunningham at the Anatomical Society on Nov. 19, 1894, it is the hinder or occipital lobes which are most deficient, these being small and in slight part only extending over the cerebellum. This fuller dimension of the occipital as compared with the frontal region serves, together with the prominence of the fore part of the condyles, to balance the facial portion of the skull, which in these cases is disproportionately large and heavy, as well as to afford space for the relatively large cerebellum. The skull-wall is in most rather thin, though in some it has the usual thickness; and in No. 7 it is preternaturally thick and heavy. This last condition of hyperostosis may perhaps result, as it appears to do in some crania of the ordinary size and character, from addition to the interior and to the diploetic substance consequent on a shrinkage of the brain. It is observable in the skulls of some aged persons.[1] The holes and grooves for blood-vessels are small, which is chiefly noticeable in the carotid foramina and canals; and the holes for the transmission of nerves are also rather small, which accords with the usually deficient growth and muscular development of the limbs and the want of proper voluntary control over them in this class of persons. In the interior of the skull the impressions by the cerebral convolutions are in most instances faint, but in some (Nos. 2 and 14) they are well marked. The ethmoidal fossa is deep and contracted, and the clinoid and adjacent processes are usually thick and clumsy. The orbital plates of the frontal bone are also thick in Nos. 2 and 14, and the upper edges of the petrous bones and the margins of the grooves for the petrosal and other sinuses are pronounced.

This thickness of the projections from the base into the interior of the skull-cavity, which reduces the size of the cranial fossæ, appears to be a common, and is a remarkable, feature in

[1] See my *Treatise on the Human Skeleton*, pp. 56 and 194; also my Work on *Old Age*, pp. 20 and 101.

An idiot's skull with thick diploe is represented by Lobstein, *Traité d'Anat. path.*, pl. iii. fig. 3.

the idiot skull. It occurs where the skull is thin (Nos. 2 and 10) as well as where it is thick (No. 12), and is not easy to account for. The thickening of the skull, attributable to shrinkage of the brain above mentioned as occurring in some senile and other persons, is usually most marked in the vault, and does not so much affect the base. Possibly this thickening at the base of the idiot skull may be attributable to the circumstance that the periosteum and bone-forming cells not being duly expanded or stretched, and being, therefore, somewhat clustered together, may vent themselves, as it were, in producing an undue thickness of the bones, much as occurs in some rickety bones where deficiency in length of the shafts, from imperfect growth at the epiphysial lines, is associated with undue thickening of their walls. This, together with the need for giving space to the auditory organ with its canals, may account for the contorted and bulging, as well as thickened and contracted, form of the petrous portions of the temporal bones noticed in Nos. 18 and 19.

Nothing particular is observable in the pituitar fossa. The frontal sinuses are rather large in some skulls.

In Nos. 1, 2, and 14 the parietal eminences are somewhat prominent. This, together with the flatness of the temporal fossæ, gives to some extent the features which constitute what is known as the "ill-filled skull." In others, however, the parietal eminences are not prominent, or the region around them unusually flat. The sutures are partially obliterated in Nos. 4 and 10, and in the latter the styloid processes are also ankylosed, though the skull is generally thin and light; and in No. 6, from a girl æt. 4, where the skull is also light, the parietal bones are ankylosed together, as in the condition termed "scaphocephalous."

The facial part of the skull, though on the whole actually rather small, is large relatively to the rest of the skull, and is rendered prominent by the deficient development of the cranial part, and especially by the backward slant of the frontal bone. The disproportion between the facial and cranial part of the skull is associated, in the marked cases, with depth of the temporal fossa and its disproportionate extension upon the skull, carrying the temporal ridge upon the parietals nearer to the sagittal suture than is normal in the human skull. In like

manner, the superior occipital ridge ascends to a relatively high level. The orbits are rather small, and the septum between them is narrow. The superciliary ridges are pronounced, which is due chiefly to the backward slope of the squamous part of the frontal bone and the upward slope of the orbital parts, and not to any special development or growth in themselves, forasmuch as the lower margins of the orbits are advanced to a level in front of the upper, and the lateral margins of the orbits slant from above downwards and forwards. Corresponding and continuous with this slant is the forward slant of the nasal and superior maxillary bones, as well as of the malar bones, productive in some instances of a more or less preternaturally marked retiring angle in the nasal bones. In some, however, the facial bones are more vertical, and the prognathous character little or not at all marked. The upper incisive alveolar processes and teeth run forward, adding much to the prognathous character of the face, but the lower alveolar processes and teeth are in most instances vertical, or they may even be directed backwards, as is markedly the case in No. 10, where the chin is prominent, after the type of the edentulous senile face. The difference in the direction of the alveolar processes and teeth, above and below, is to a great extent compensated for, and the cusps of the upper and lower teeth are brought nearly to the same plane by the openness of the angle between the horizontal and ascending parts of the mandible, which, as in senile specimens, throws the body of the jaw forwards. The teeth are of about the usual size, appearance, and relation to one another. In some, as No. 14, the space for them in the upper jaw is gained by the slant of the anterior alveolar processes of the maxilla; and in others, as No. 11, chiefly by the general slant of the whole maxilla and the facial bones. In some specimens the face is narrow or pinched; and in these the palate is preternaturally arched, the two conditions going together. In other cases the face is fairly wide, the alveolar processes having nearly their normal sweep, and the palate having its normal arch and shape.

The several features which I have mentioned are present in varying degrees in the several specimens, but in none is there any question of the skull appertaining to a member of the

human family: in many the chin is large and prominent, and in all the position and direction of the occipital condyles are indicative of the erect posture. A resemblance to the lower animal type, shown in the prognathous character of the face and upper alveolar processes and teeth, and in the abnormal size of the facial bones and the depth of the temporal fossæ, so marked in No. 19, is due mainly or altogether to the deficient size of the cranial part, owing to the defective development of the brain, and is a morbid feature, a result of special failure in development rather than a racial phenomenon.

The obliquity, or prognathism, of the facial part is caused mainly by the obliquity of the frontal bone, whereby the malar bones are carried forwards, and with them the maxillæ. Forasmuch, however, as the large proportionate size of the normal brain, and the consequent expansion of the brain-case, is a human feature, and is most marked in the higher members of the human family, so does the imperfect development of the idiot brain bring the skull into closer similarity to the lower human and the lower animal types.

The obliquity of the upper incisive and canine sockets and teeth seems to be due mainly to the disproportion in size between the teeth and that of the maxilla, a disproportion not uncommonly observed in persons who are in other respects fairly developed, and which in them is usually attended with a crowding of the teeth rather than with the forward slant in the alveolar processes and teeth by which, as we have seen, the requisite space is commonly gained in the idiot jaw.

There is nothing in the specimens to suggest that the deficiency in the development of the skull was the leading feature in the deformity, and that the smallness of the bony cerebral envelope exerted a compressing or dwarfing influence upon the brain, or anything to give encouragment to the practice lately adopted in some instances of removal of a part of the bony case, with the idea of affording more space and freedom for the growth of the brain. In these, as in other instances of Man and the lower animals, the brain-growth is the determining factor, and the skull grows upon and accommodates itself to the brain, whether the latter be large or small. This view is corroborated by the fact that, in the brains taken from the two idiot skulls in

St Bartholomew's, as well as in other instances as those shown by Professor Cunningham, the convolutions of the brain give no indications of compression, but are free, outstanding, and separated by well-marked sulci.

I do not know that it is possible to distinguish with certainty, from the observation of the skull alone, the instances in which the idiot or microcephalic condition was due to disease, from those in which it resulted from simple atrophy or failure during the period of development. It seems, however, probable that in the more marked cases, such as Nos. 1, 2, 4, 5, 6, 7, 8, 9. and especially 7, 15, 18, 19, the condition was due to an early arrest of development. In Nos. 3 and 10 it may be inferred that the accumulation of fluid in the ventricles was the cause of the failure of brain-growth. In the remainder it must be uncertain whether the condition was due to primary defective developmental power or to defective growth induced by disease.

The openness of the angle formed by the neck of the thigh-bone with the shaft, which is observed in Nos. 3, 8, and 10, is probably due to the part not having been subjected to the weight of the body. The same condition occurs in limbs affected by infantile paralysis or any cause which prevents the patient bearing upon them in early life.[1]

1. In the Museum of the Royal College of Surgeons of England are two marked specimens of idiot skulls. One, numbered 95A, is from an adult male in India, who is reported to have been a mere idiot, though gifted with some powers of imitation, to have been 5 ft. 6 in. in height, and to have weighed 89 lbs. The greatest circumference, round forehead and occiput, is 14 inches. The parietal prominences are, but the frontal are not, pronounced. The frontal bone is almost horizontal; the occipital, including the hinder part of the foramen magnum, slants upwards. The occipital condyles are gone (broken or cut off). The mastoid processes are large. The supraorbital ridges are pronounced; the interorbital septum is narrow; the roofs of the orbits are arched; the nasal bones, the lateral margins of the orbits, and the superior maxillary bones slant somewhat forwards, and also the aveolary processes, forming a prognathous feature; but these bones are not much below the average size, and the palate is nearly as wide and not more arched than usual. The lower jaw is wanting. The temporal fossæ are proportionally large

[1] See paper by me on this condition of the neck of the thigh-bone in the *Illustrated Medical News*, iii., p. 1, and in this *Journal*, xxiii., p. 367.

and flat and extensive. The foramina at the base, especially those for the carotids, are small. (The skull cavity has not been opened.)

2. The other specimen, numbered 95B, is from a woman æt. 24, a congenital imbecile, who died in Earlswood Asylum, and whose brain weighed 16 oz. The greatest circumference of the brain-case is 14·2 inches. The parietal eminences are pronounced, but not the frontal. The occipital condyles are very prominent, which results from the sloping upwards of the squamous part of the bone behind and of the basilar part in front. The mastoid processes are large. The carotid foramina are small; the other foramina of moderate size. The bones of the skull generally are thin, but the crista galli of the ethmoid and

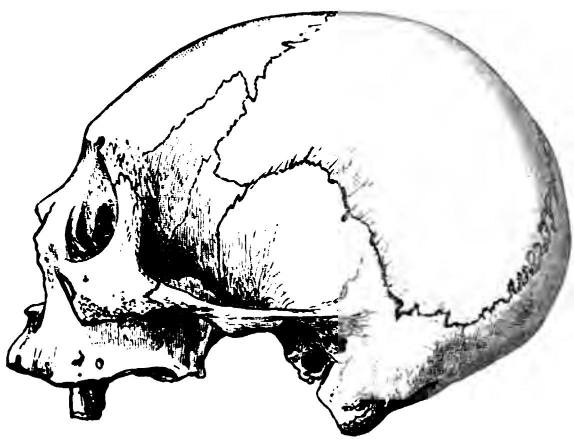

FIG. 1.—Skull I.

the clinoid processes of the sphenoid are thick. The orbital plates of the frontal bone are also thick and arched, and are marked by the cerebral convolutions, and the squamous part is slightly so. The supraorbital margins are pronounced. The bones of the face project forwards, more so than in No. 1, and they are narrow (pinched), and the alveolary arcade is consequently narrow, and the arch of the palate is high and contracted. The temporal fossæ are flat and proportionally rather large and extensive. The ethmoidal fossa is contracted by the prominence of the orbital plates of the frontal bone.[1]

3. Mr Alexis Thomson, in Edinburgh, showed me the bones of an idiot female who died at the age of 30; and he has since been good enough to send me a photograph of the skull from which the woodcut No. III.

[1] The photographs from which the woodcuts I. and II. were taken were kindly sent me by Professor Stewart.

has been taken. Nothing abnormal appears to have been observed in the child at birth, but the right side was noticed to be weak when she was about a year old. She did not grow well, and was confined to bed

FIG. 2.—Skull II.

all her life. The limb-bones are small and thin ; the angles of the necks of the thigh-bones 142°. The skull is of about the ordinary thickness and density, and has a circumference of 16 inches. The frontal sinuses

FIG. 3.—Skull III.

are large; the ethmoidal fossa narrow and compressed; the clinoid processes and other projections in the interior rather pronounced; the

carotid foramina small, and the nerve foramina rather small; frontal bone very sloping, the occipital less so; superciliary ridges prominent; bones of face thin, sloping (prognathous); upper alveolar processes and teeth much so; the lower vertical rather slanting backward, and the angle of the jaw open (125°); the palate normal; sphenoidal and spheno-maxillary fissures wide, especially the former.

4. In the Anatomical Museum of the University of Edinburgh is the skull of a male idiot, circumference 18·5 inches. The weight of the brain was 27½ oz.; frontal bone very sloping, occipital less so; condyles very convex; clinoid processes and margins of petrous bones thick, clumsy; orifices for vessels small, for nerves less so; channels for sinuses rather small; calvarium rather dense; the frontal eminences flat, and the frontal sinuses prominent. There are knotty, uneven processes on the exterior of the skull near the coronal suture. The sagittal suture is obliterated, and the other sutures are so partially. The superciliary ridges are very prominent, yet are on a level behind the lower margins of the orbits. The jaw-bones are of fair size, and not very prognathous.

5. The skull of an idiot girl æt. 15, in the same museum; rather thin and light, weighing 16½ oz.; circumference 19·5 inches; carotid holes small. The upper alveolar pr. and teeth slant forwards; the lower nearly vertical; angle of jaw 133°.

6. The skull of an idiot girl æt. 4, in the same museum, is small and light, weighing 11½ oz., scaphocephalous, the sagittal suture obliterated. The frontal bone is beetling; occipital slanting upwards from foramen magnum; face nothing peculiar; palate normal.

7. In the Museum at Würzburg is a microcephalic skull only 12 inches in circumference. It is thick and weighty, and the mastoid processes are large. The frontal bone is very flat, almost as in acephalous cases, and the occipital bone rises suddenly from the condyles which are thus, and by the sudden ascent of the basilar part, thrown into strong relief; and they are rather more curved, convex from before backwards, than usual. The foramen magnum is of the usual size. The flexure at the base is increased by the obliquity of the basilar portion, though lessened by the slant of the vomer and face forwards. The sutures are quite distinct. The connections between the sphenoid and parietals are wide, and the temporal fossæ are deep. The superciliary ridges and the intervening fronto-nasal region are thrown into strong relief by the flatness of the frontal above them, though they are in a plane considerably behind the infra-orbital ridges. The orbital plates of the frontal slant a little upwards, and the orbits and facial bones are nearly of the usual size. The latter are very prognathous, the upper alveolar processes and teeth slanting much forwards; whereas the lower are nearly vertical, and the lower jaw is large and strong, with an open angle.

8. In the skeleton, at Vienna, of a scarcely adult idiot, 3 ft. 3 in. in height, with small, slender, sprawling limbs, and open angles of thigh-bones, the skull much resembles that last described; the face prognathous, with alveolar processes and teeth slanting above and vertical below; the chin prominent, and the angle of the jaw wide.

9. In Berlin is a similar skeleton to that in Vienna, small, with extremely small skull, the facial part of which is of fair size and prognathous. I could not take measurements of either of these crania

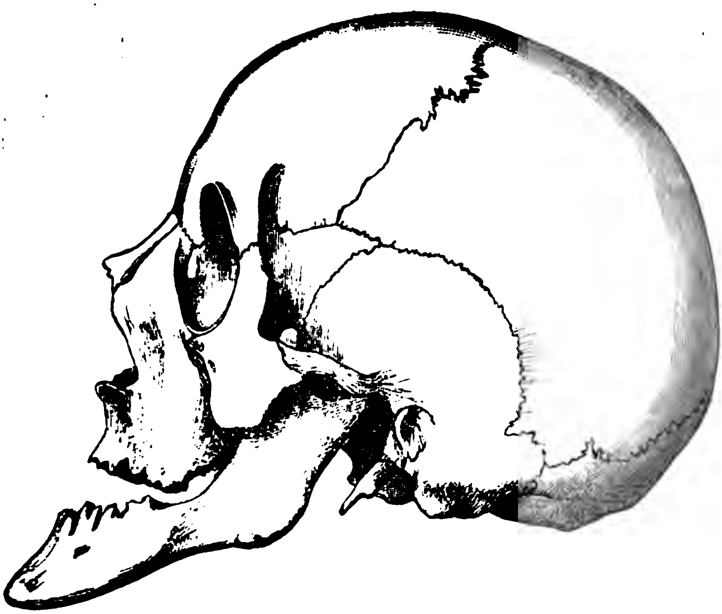

FIG. 4.—Skull X.

(8 and 9) owing to the difficulties, in both these museums, of obtaining access to the specimens.

In the Cambridge Museum are the five following specimens, in none of which are the features so strongly marked as in the preceding.

10. (1461E) is from a male idiot æt. 19, in whom idiotcy was attributed to convulsions occurring when he was eleven months old, but the post-mortem examination showed that this condition was probably congenital. He never walked, but lay till his death, which

took place in a lunatic asylum, on his back, with his limbs bent, not speaking or taking notice of anything, and his food had to be put into his mouth. The skull is small in all its dimensions, but the several parts, except the lower jaw which is long, are fairly proportioned to one another. It is thin and light, weighing under 11 oz. (The exact weight cannot be determined, because part of one orbit and of the side of the skull has been cut away.) It is narrow, especially in the fore part; circumference 17·5 inches. No marked prominence of parietal or frontal protuberances, or other appearances indicating the "ill-filled" skull. The occipital condyles are prominent and rather convex. The foramina are rather small; the markings of the cerebral convolutions very faint. The crista galli, the clinoid processes, and the other projections into the interior are rather thick and disproportionately pronounced. The sagittal suture is quite obliterated, and the styloid processes are ankylosed. The coronal suture is nearly obliterated in the interior, and the other sutures are so to some extent. The orbits are rather small; the opening 1·5 by 1·3. The frontal sinuses are fairly developed. The superior maxillæ are small and are compressed laterally, giving a pinched character to the face. The nasal arch is high and narrow; the nasal spine and the median ridge descending from it between the incisive alveolar sockets prominent. The nasal septum bent to the right, and ankylosed to the inferior spongy bone; the arch of the palate narrow and high. No marked prognathism though the upper incisive alveolar sockets, which are small and crowded, slant a little forwards; the corresponding sockets in the lower jaw slant backwards, rendering the chin very prominent, and the body of the jaw is disproportionately elongated, measuring 4 inches. The angle of the jaw is 145°. In short, but for the presence of the tooth-sockets, the lower jaw presents the appearances usually observed in the senile edentalous condition. The limb-bones, which are also in the museum, are small and thin, as in infantile paralysis, and the angles of the thigh-bones are very open.

The brain of this case is fully described by Dr Hill in the *Journal of Anatomy and Physiology*, xix. 363. It was small; the ventricles greatly dilated with fluid, and their covering for the most part merely thin membrane, which, I suppose, may be regarded as a condition similar to that which is thought, when it occurs in an early stage of development, to be the cause of the acephalous monstrosity "ectopia cerebri."

11. (1461F.) The skull of a female idiot about 18 presents generally the same features as the preceding. It is small and thin, weighed 16 oz., and the forehead is low and narrow; the circumference is 18·5 inches; the sutures are all free. The parietal prominences are slightly more pronounced than in 10; but here, as in it, there are little indications of the "ill-filled" condition of skull. The carotid foramina are small, but the neural foramina are only slightly less than the usual size. The cerebral eminences and depressions are fairly marked on the orbital and other parts of the base, and the various pro-

cesses and ridges in the interior are rather pronounced. The frontal sinuses are large; the occipital condyles are prominent; the orbits are rather small, 1·3 by 1·3, their lower margins being well in front of the upper. The alveolar processes of the upper jaw, as well as the bones of the face generally, are prognathous. The incisive and canine teeth are more oblique (prognathous) than those in the lower jaw, and the lower incisor teeth meet the upper further back than usual. The angle of the jaw is about 135°. The whole face rather small.

12. (1461G.) Skull stated to be that of an idiot of about middle age. It is of nearly the same size as the preceding, but the cranial bones are thicker, with thicker diploe. It weighs, without the lower jaw, which is wanting, 16 oz.; the circumference is 19½. The parietal prominences are not marked; the forehead is less narrow than in Nos. 10 and 11; the sutures are open. The cerebral eminences and depressions are well marked at the base. The crista galli and clinoid processes are rather large, and the petrous bones are thick. The occiput

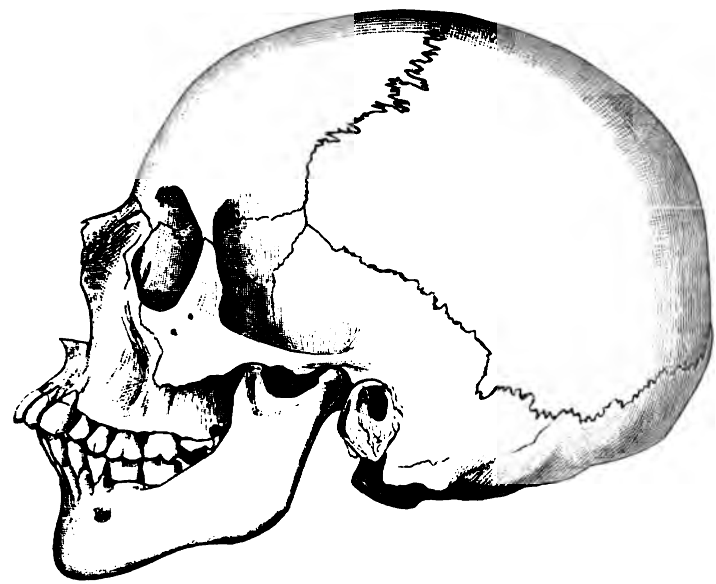

FIG. 5.—Skull XIII.

slants upwards from the foramen magnum, but the basilar part does not slant much upwards from the condyles. There is very little prognathism. The maxillæ and the palate are well developed; the face is broad, and presents little of the usual appearance of the idiot skull.

13. (1461K.) The skull of an idiot male æt. about 19. The cranial part is fairly developed, and has a circumference of 19 inches. The skull-wall is rather thick and dense; the skull weighs 20 oz. The markings of convolutions on the interior of the base very distinct. The orbital plates of the frontal bone rather coarse and thick, and the ethmoidal fossa rather deep; the clinoid processes somewhat thick; pituitary fossa natural; the foramina at the base of fair size. The basilar portion of the occipital slants more upwards than usual. The face is rather narrow, pinched, and the palate rather high. All the facial bones slightly slanting; the alveolar parts of the maxilla and the upper incisors markedly so. The alveolar processes and incisor teeth of the lower jaw nearly vertical, and the chin fairly prominent. The angle of the jaw is 132°. None of the sutures ankylosed.

The deficiency in cranial capacity in this case is chiefly at the under and fore part, consequent on the upward slant of the basilar part of the occipital and the convexity of the orbital parts of the frontal. The face presents the idiotic type more than several of the preceding specimens, and the prognathism of the alveolar processes is associated with narrowness of the dental arcade.

14. (1461H.) Skull of a female idiot æt. 19; circumference 18·7. The parietal prominences are more prominent than in any of the other specimens. The sutures are all open; the forehead slopes backwards. The clinoid and other processes in the interior are thick, as are also the margins of the petrous bones. The skull-wall generally is rather thick, with well developed diploe. The cerebral markings on the orbital plates are strongly marked, less so in other parts of base. Carotid and other foramina rather small; occipital condyles prominent; foramen magnum large, and the diameter from before backwards prolonged. The slanting upwards of the squamous and basilar parts of the occipital bone is not very marked. The margins of the orbits are pronounced all round. The upper alveolar processes are markedly prognathous; the bones of the face less so. The lower jaw is thick and strong, with an angle of 120°.

There is also in the Thurnam Collection in the same museum the calvarium of a "male idiot æt. 50." It is narrow, especially in the fore part. It is thin, rather dense, and the sutures partially obliterated.

Professor Cunningham kindly sent me the two following (Nos. 15 and 16), which, as well as No. 17 sent by permission of Dr Frazer, are in the museum of Trinity College, Dublin.

15. The skull of Frederick Bibley, an adult, 16½ inches in circumference. It is of about average thickness, and the clinoid and other processes at the base do not present any of the distinct thickness or clumsiness noted in some of the other cases. The size of the cerebellar part is much larger in proportion than that of the cerebral. The orbital plates of the frontal bone are much arched and marked by

cerebral convolutions, which is the case also, though in less degree, with the upper part of the frontal bone. The frontal bone slants much backward, and the fore part of the skull is much contracted, more so in proportion than the occipital. The frontal sinuses are fairly developed. The temporal fossæ are deep and flat, and relatively large. The coronal suture is obliterated at the sides, and the sagittal suture is in parts obliterated, which is also the case with the fronto-nasal, the nasal, and the sutures connecting the malars with the adjacent bones. The squamous and basilar parts of the occipital slant much

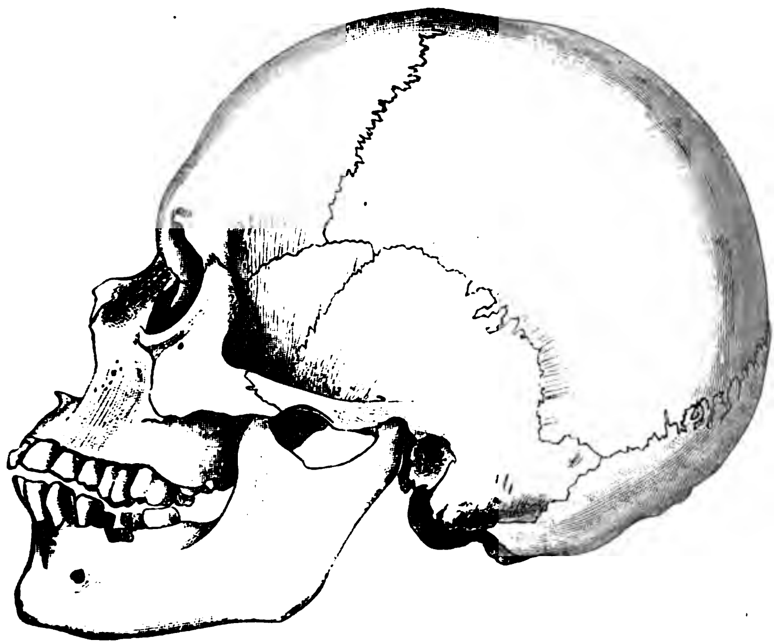

FIG. 6.—Skull XIV.

upwards, leaving the condyles very prominent, especially at their fore parts. The foramen magnum is large, but the other foramina are rather below the usual size. The orbits are fairly formed, and their lateral margins are less slanting than in the ordinary idiot skull, and the facial part of the skull must have been less prognathous. The lower part, however, has been broken away. The remaining walls of the antrum are thin like those of aged and edentalous persons; and the hinder parts of the upper alveolar processes, which alone remain, indicate the edentalous condition. The superior occipital ridge ascends high, and is prominent. The temporal ridges also extend to within 1½ inch of the sagittal suture. The skull is prominent along the median line to the back part of the parietals. This is caused by a bulging of the bone, and gives some enlargement to the cranial cavity.

The cast of the brain shows great deficiency in size of the cerebrum, especially in the fore and hinder parts, the cerebellum, as indicated by the skull, being large in proportion to the cerebrum.

16, though small, is fairly well shaped; the forehead duly prominent; the orbits well formed; the facial bones vertical, but the upper incisive alveolar processes and teeth slant forwards. The

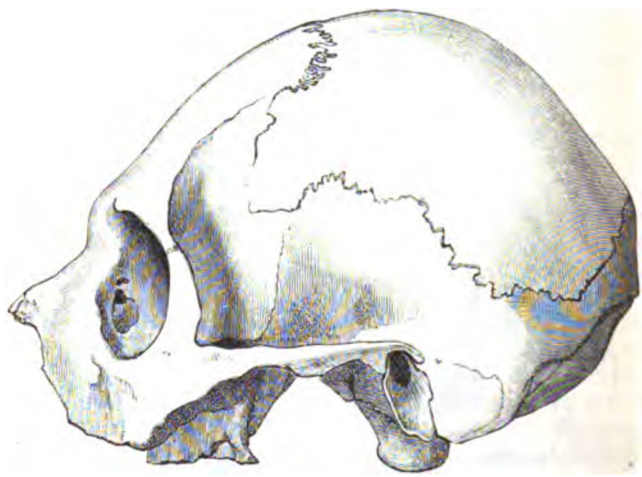

FIG. 7.—Skull XV.

temporal fossæ relatively normal, as also are the clinoid and other processes in the interior. The condyles not unusually prominent, nor are the parts of the occipital bone, in front or behind, markedly oblique.

Professor Cunningham has also sent me the upper part of a calvarium of Frederick Russell, which is remarkably small, 4·3 inches in length and 3·75 in width.

17. A skull found by Dr Frazer in a charnel mound near Donnybrook (see *Journal of Proceedings of the Royal Society of Antiquaries of Ireland*, 1892), and placed by him in Trinity College, Dublin. In his letter to me, Dr Frazer speaks of it as probably the *oldest* microcephalic specimen known. It has a circumference of 17·25 inches, and does not markedly present the idiot type. The frontal bones are somewhat sloping, and the superciliary ridges prominent. The occipital bone slightly deviates from the horizontal. The occipital protuberances are prominent, but not the parietal or frontal. The facial bones are small on the whole, fairly vertical, but the upper incisive alveolar process and teeth slant forward, the lower teeth also slant somewhat forward. Angle of jaw 114°.

18. (St Bartholomew's Museum, No. 3441.) Well-marked idiot type of skull, woman æt. 22. A light, thin wall, with a circumference of 11½ inches. The impressions of the cerebral convolutions on the squamous and orbital parts of the frontal bone rather faint. Ethmoidal fossa very narrow, and encroached upon by convex orbital plates. Ethmoidal crest thick. Petrous portions of temporal bones thick, stunted, hillocky, running forwards on the inner side of the Gasserian fossæ, with prominent semicircular canals. Foramina at base small. Frontal bone very sloping, contracted laterally, and with projecting superciliary ridges. Occipital condyles very prominent, especially in their fore parts; and the slant in the occipital bone includes the part of the foramen magnum behind the condyles. Face rather small, very prognathous, and the upper incisive alveolar processes and teeth also much slanting, the lower nearly vertical. The angle of the lower jaw very open. Teeth all good, and of fair size. Temporal fossæ not very large, and jaws rather thin. The brain preserved in spirit shows the convolutions large, simple, prominent, and with clear intervening sulci. The hemispheres of the cerebrum are prolonged very slightly over the cerebellum.

19. (St Bartholomew's Musuem, No. 3443.) Well-marked idiot type of skull, rather thick. Ethmoidal fossæ rather narrow and crest thick, clinoid processes also thick, and petrous portions of temporal bones remarkably thick, hillocky, and misshapen, as in preceding case; orbital plates and fore part of skull well marked by cerebral convolutions. Foramina at base rather small. Frontal bone sloping, throwing superciliary ridges into prominence. Squamous part of occipital bone also sloping, and throwing condyles into prominence. Temporal fossæ large and deep, especially behind external angular processes of frontal bone, which, like the superciliary ridges, stand out in strong relief. The facial bones large, strong and prognathous; the teeth sound and large. The upper incisive alveolar processes and teeth slanting, the lower vertical. The maxillæ and mandible thick, large, strong, with prominent chin. The thick, heavy jaws, and large, deep temporal fossæ, as compared with the corresponding features in No. 18, accord with the thicker skull and the male sex.

Professor Carl Vogt (*Anthropological Review*, vii. 128) says that, despite long-continued researches, he has, in the whole scientific literature, found notices of only about forty cases of microcephaly, "and even of these there are probably some belonging to the category of idiotism from disease." He gives a list of them.

The Hydrocephalic or Macrocephalic Skull.

The ten specimens from which the following account is given are in the Cambridge Museum:—

1. In a child about 4, the skeleton of which is represented in this *Journal*, xxiii., p. 367, the skull is nearly globular, and has a circumferen-

tial measurement of 26 inches; the squamous parts of the frontal, parietal, and occipital bones are of enormous size, and the interval of more than an inch between the occipital and parietals, and extending up between the latter, is occupied by wormian bones. There appear to have been large wormian bones in the sagittal suture, but these have for the most part become quite blended with the left parietal. The skull-case is complete, with the exception of a few gaps in the sagittal suture. The frontal suture is quite obliterated, as is also the coronal suture on the left side, there being scarcely a trace of it remaining, and the lower part of the same suture on the right side is beginning to disappear; the sutures also of the frontal, with the great alæ of the sphenoid, with the ethmoid, with the nasal bones, and with the nasal processes of the maxillary bones, have partially disappeared; and the same is more or less the case with the sutures between the maxillæ with the nasal bones, the malar bones, and the ossa anguis; also with those between the nasal bones and those between the maxillary and the palate bones. The expanded bones of the skull are remarkably dense, ivory-like, and polished. The orbits are large, and the orbital margins are extended upwards by the dragging up, as it were, of the squamous parts of the frontal bones, carrying up with them the superciliary ridges which are less pronounced than usual. As a consequence of this elevation of the superciliary ridges the orbital plates of the frontal bone are very oblique, slanting, from behind, upwards as well as forwards. The lower or malar margins of the orbits are more pronounced and sharp than usual, and the orbital axes are oblique, slanting from behind upwards and forwards. The margins of the lacrymal canals, especially the under margins formed by the ossa unguis, and the ridges of the frontal bone ascending from them, are dragged into relief, giving preternatural breadth to the nose. The temporal fossæ are shallow in consequence of the alæ of the sphenoid, and still more of the squamæ of the temporals, being bulged outwards. The nasal part of the skull is wide. The maxillary and other facial bones are rather large; the chin unusually developed for the time of life; and the ascending portions of the lower jaw, behind the teeth, slant outwards to conform with the widened base of the skull and the greater space between the glenoid cavities. The malar bones in like manner slant outwards. The trunk- and limb-bones appear of natural length, but are very slender, not fitted to bear the weight of the head, and indicating that the recumbent posture was habitual; and the angles of the thigh-bones are remarkably open.

The point of interest here is the amount of ossification which took place in the stretched envelope of these enormously dilated cerebral hemispheres, which was not only sufficient to cover them with a complete bony case, and lead to great density as well as great enlargement of the individual bones, but which, moreover, exceeded the requisite bounds, and produced unusual and premature ankylosis of the bones by obliterating the sutures.

The stretching of the enveloping ossifying membrane, that is to say, has led not only to a sufficient increase of its substance to form a covering, it has, further, induced an exaggerated hyperplasia in it. A similar increase, to some extent, must have occurred in the other envelopes, the dura mater, the skin, and the tissues between them; but I do not know that the increase in these was so redundant as in the case of the ossifying tissues. Similar increase, the effect of dilating pressure, is observed in other parts, and under various circumstances—in the envelopes, for instance, of many cysts, in the uterine walls when stretched by growths, not to say the growth of a fœtus, and generally in the capsules or coverings of cysts and tumours; and in some of these instances the increased cell activity leads to considerable thickening of them. I am not aware whether or not the stretched brain-substance undergoes an increase in amount in hydrocephalus, but the stretched lining of the ventricles commonly does so. The extension of the superabundant bone-growth to the face, causing premature ossification of sutures and enlargement of the facial bones, is also interesting.

In the skull of a quite young (about birth) hydrocephalic child at Munich, the lower parts of the frontal and the temporo-parietal sutures are synostosed, though the sagittal suture and the fontanelles are unclosed. In the hydrocephalic skull, measuring 26 inches, of a child in Würzburg, the parietal lambdoidal and other sutures are partially synostosed; and in another specimen, somewhat older, where the skull is elongated, the sagittal suture is quite obliterated.

There are four skeletons of hydrocephalic children, much resembling the above, in the Musée Dupuytren at Paris. In each the skull is ossified all over; but the specimens being in glass cases, I could not see whether there was synostosis at the sutures in any. In a similar specimen in Vienna the skull is of enormous size and the frontal suture obliterated, but I could not see other evidence of synostosis; the base of the skull is wide, as is also the face, the rami of the inferior maxilla slant outwards above, and the teeth are further apart than usual.

2. The skull of a child, rather younger than No. 1, has more the

ordinary oblong form. Its circumferential measurement is 24½ inches. The calvarial bones are of great size, but all the sutures, including the frontal, are open. The facial bones are not large, but vertically ranged, and overhung by the forehead. The frontal, the parietal, and the occipital eminences are well marked.

3. The hydrocephalic skull of an eight month fœtus, with a circumference of 18 inches, presents in a remarkably prominent manner the ossifying centres of the frontal parietal and occipital eminences. This is also the case in another specimen at about the time of birth.

These frontal and parietal eminences are a remnant of fœtal life when the bones were moulded upon, were casts of, the small early brain. During the growth of the brain, and till the approximation or interlocking of the bones at the sutures takes place, they retain their original convex form, being simply carried outwards, while the parietal and frontal bones are growing at their circumference. When, however, the skull is closed in, and the further change and growth in it continues to be due to further growth of the brain, and consequent uniform pressure in the interior, then these prominences become more or less obscured by the outward growth of the circumferential parts of the bones, and the closer moulding of the whole upon the enlarging brain. They are therefore least observed when the brain enlarges most; and most so, giving rise to the form known as the "ill-filled skull," when the brain enlarges least.

4. In a hydrocephalic child under 6, the skull has a circumferential measurement of 24 inches, and a remarkably square form, which is mainly due to the prominence of the frontal and parietal eminences. The occipital eminences are prominent. The frontal bone overhangs the face, which is vertical and wide. It weighs 6½ ounces. There are isolated gaps or apertures from deficient ossification in the right parietal, which, nevertheless, like the other calvarial bones, is of large size. These gaps are common in the hydrocephalic skulls of the young, and are occasionally seen in the orbital plates. The sutures, including the frontal, are open, and there is a large unossified area in the region of the anterior fontanelle.

The expansion in these cases affects all the parts, the vault, or least resisting part, most, but the base also in some degree, causing an elongation of it, which in some instances is very perceptible in the basi-sphenoid and basi-occipital region, causing also a widening of it, which is evinced by the distance

between the glenoid cavities, and by the splaying out of the petrosal parts of the temporal bones and of the ridge formed by the lesser alæ of the sphenoid bone.

The following five specimens are from adults :—

5. The skull of a hydrocephalic man aged 43; circumference 24 inches. It is well formed, of at least ordinary thickness, and rather greater density than usual. The face is large and strong, and the chin is very prominent, which is from growth of the mental portion of the lower jaw rather than from any alteration of the angle, which is 120°. The orbits are rather large, of natural form, with horizontal or flat roofs, and well developed superciliary ridges. The nasal bones are long, and overhung by the frontal. The temporal fossæ are shallow. The impressions of the cerebral convolutions are well marked on the orbital plates and in the middle cranial fossa, and faintly in other parts.

6. A hydrocephalic adult (Romano-British?) skull, with a circumference of 24½ inches. The coronal suture is partially obliterated; there is a slight trace only of the frontal suture. The face is well formed and strong; the intermalar measurement 4·7. The roofs of the orbits are flat, and the superciliary ridges are well developed. The lower jaw is wanting.

7. Adult. Circumference of skull 25 inches; weight 32 oz.; sutures nearly obliterated in the interior; faintly marked by cerebral convolutions on the frontal and orbital parts. The face is well developed and the orbits well formed, except that the roofs are somewhat slanting, as in the infantile cases, and the superciliary ridges are well developed. Lower jaw rather small, with an angle of 108°. Parietal eminences rather pronounced.

8. Adult. Circumference 23½ inches. The sutures, including the frontal, are open; a few small wormian bones along the occipital suture; parietal prominences not marked; neither squamous nor basilar parts of occipital unusually depressed, that is to say, not descending below the usual level behind or in front of the foramen magnum; foramina at base large, especially those for blood-vessels, and the foramina ovalia are also large; glenoid fossæ large, deep, and far apart; occipital condyles rather small; face and interorbital septum wide; orbits well formed, and superciliary ridges also well developed; nasal spine prominent; alveolar process beneath it short, and the right middle incisive socket slants rather obliquely forward; the left has been absorbed (all the upper teeth are gone). The dental arcade is rather wide. In the lower jaw the alveolar processes have been absorbed, except those of the incisive canine and bicuspid teeth; these teeth remain; the angle is very open (135°); the chin is prominent, and the whole bone is thin; the temporal fossæ shallow and

the walls bulging, especially the parts formed by the squamous portions of the temporal bones. The parietal prominences not marked.

9. Adult. Circumference 25¼ inches. The squamous and basilar parts of the occipital do not descend below the usual horizontal level. Sutures, including frontal, are all free; a few small wormian bones in the occipital and the left temporo-parietal sutures. Face vertical and large, between malars 5·1. Orbits large, well formed, with horizontal roofs; dental arcade large and wide. Temporal fossæ flatter and deeper than in the preceding specimens. Lower jaw large and strong; chin rather prominent; angle 110°.

10. Adult calvarium, with a circumference of 23½ inches; not thick, but hard, and indented in all its inner surface by cerebral convolutions. The sutures open. Small osteophytic growths on the sides of the groove for the frontal sinus. Similar growths in two of the other skulls. Parietal eminences rather prominent.

In these five adult crania the disproportion between the brain-case and the facial part is not so marked as in the infantile specimens, which is attributable in part to the predominant growth of the facial part in early extra-uterine life, and partly to the hydrocephalic disease being less in amount, and allowing the adult period to be reached, and the adult relation between the facial and the cranial parts to be, to a certain extent, attained; and it is to be remarked that the excessive growth of the cranial part of the skull is associated with, directly or indirectly productive of, some excessive growth of the facial parts. This also probably accounts for the fact that in most of the adult specimens the orbits have their natural shape, and do not present the obliquity in their roofs caused by the pressure of the intraventricular fluid, which is so marked in the infantile specimens.

In St Bartholomew's Museum is a remarkable specimen of the deformed head of a child who lived only a few days after birth, in which the cerebral hemispheres are piled up in front, so that the corpus callosum and the frontal convolutions are quite vertical, and the orbital plates have, by the pressure upon them, been rendered also quite vertical. The eyes, in consequence, have been pushed forwards so as to lie in front of the eyelids, and were covered hy highly vascular conjunctiva. This is an exaggerated orbital condition of what occurs from

pressure, though by a different cause, in the hydrocephalic infant.

It is obvious that the differences between the microcephalic or idiot skull, and the macrocephalic or hydrocephalic skull, are referable simply to the differences in the size of the brain-case in the two, which are again referable to the differences in the size of the brain.

In the microcephalic, the brain case is small or contracted in all its dimensions, in the base as well, though less than in the vault; and it is most so in the fore part, the frontal bone being sloped back and narrow, with deep temporal fossæ behind the external angular processes, and with curved orbital plates, which narrow the ethmoidal fossæ. The parts in the interior are contracted and often thickened. The occipital condyles are rendered prominent by the sloping of the squamous and basilar parts of the bone behind and in front. The superciliary ridges are thrown into prominence, and the frontal sinuses are large. The facial bones, smaller than normal and less wide, with a narrower dental arcade, though proportionately large, are prognathous, the upper incisive alveolar processes and teeth being especially so. The angle of the lower jaw is more open than usual. The foramina at the base are usually small.

In the macrocephalic all this is reversed. The brain-case is expanded in all directions, to some extent in the base, but much less than in the vault. The forehead bulges forwards, beetling over the face; the orbital plates are in the young flattened and pressed down, and the superciliary ridges are elevated and suppressed. The temporal fossæ are shallowed, and the occipital condyles are not prominent. The face, though in many larger than ordinary and widened, the dental arcade being wide, and the rami of the maxilla being slanted outwards to accommodate the condyles to the separated position of the glenoid fossæ, is relatively small, retired beneath the forehead, and devoid of prognathism.

In both the chin is prominent, and there is some tendency to hyperossification.

European.

		Circumference. — Round Glab. and Occ. Spine.	Ant. Post. — Between Glab. and Occ. Spine.	Transverse. — Between Pariet. Emin.	Height. — Front of For. Mag. to Vertex.	Over Vault. — From Glab. to Occ. Spine.	Over Vault. — From one Aud. Meatus to the Other.	Between Apices of Mastoid Pr.	Between Outer Margins of Glenoid Fossa.	Between Outermost Parts of Malar Bones.	Dental Arch. — Between Hinder Parts of Alveolar Process.
	Male.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1	(1) 653	20·5	7·	5·4	5·2	12·25	11·75	4·2	4·75	4·7	2·3
2	595	21	7	5·3	5	12·5	12	4·1	4·75	4·6	2·1
3	588	20·75	6·9	5·1	5	12·5	12	4	4·5	4·4	2·3
4	612	21·25	7·3	5·6	5	12·5	12·25	4·5	5	4·5	2·1
5	587	20·5	7·1	5·3	5·3	11·5	12·25	4·25	5	4·7	2·7
6	574	20·5	7·4	5·2	5·3	12·8	12	3·8	4·5	4·5	2·4
	Average,	20·75	7·1	5·3	5·1	12·34	12·04	4·1	4·75	4·5	2·3
	Female.										
7	(1) 1136	19·25	6·5	5·5	5	12	12	4·5	4·7	4·5	2·25
8	1155	20·5	6·75	5·75	4·6	12·25	12·5	4	5·1	4·75	2·5
9	585	20·75	7·3	5·7	5·7	12·8	13	4	4·6	4·5	2·2
10	1152	19·25	6	5·4	4·7	11·5	11·5	3·9	4·7	4·25	2
11	1089	19·5	6·3	5·6	4·9	11·25	12·5	3·8	4·7	4·5	2·3
12	572	20	7	5	48	11·5	11·25	4	4·6	4·2	2·1
	Average,	19·7	6·64	5·49	4·9	11·88	12·12	4·08	4·7	4·45	2·2

(1) Numbers in Museum of Anatomy.

Microcephalic.

No.	Mus. No.	Age.	Circumf. — Round Glab. and Occ. Spine.	Ant. Post. — Between Glab. and Occ. Spine.	Transverse. — Between Parietal Eminences.	Height. — Front of For. Mag. to Vertex.	Over Vault. — From Glab. to Occ. Spine.	Over Vault. — From one Aud. Meatus to the Other.	Between Apices of Mastoid Process.	Between Outer Margins of Glenoid Fossæ.	Between Outermost Parts of Malar Bones.	Dental Arch. — Between Hinder Parts of Alveolar Processes.	Angle of Lower Jaw.
			Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	°
1	95A., R.C.S.	M. Adult	14	5	3·7	3·8	7·5	8·5	3·5	3·7	4	2·4	...
2	95B., R.C.S.	M. 24	14·2	5·7	4·1	3·7	7	8·5	3·5	3·8	3·4	1·8	...
3	...	F. 30	16	...	...	...	9·5	10·2	3·1	...	...	...	125
4	Ed.	...	18·5	...	...	...	11·5	...	...	...	...	...	...
5	Ed.	F. 18	19·5	...	...	...	13·5	12·4	4	...	...	...	133
6	Ed.	F. 4	...	...	...	...	...	...	...	...	...	...	...
7	Würzburg	...	12	...	...	...	...	...	4	...	4·5	...	...
8	Vienna	Adult	...	...	...	...	...	...	...	...	...	...	...
9	Berlin	...	...	...	...	...	...	...	...	...	...	...	...
10	1461E.	M. 19	17·5	6·3	4·7	5	11·5	11·5	3·7	4	4	2·1	145
11	1461F.	F. 18	18·5	6	4·9	4·7	11	11	2·7	4	4	2·3	135
12	1461G.	Adult	19·5	7·1	4·9	4·8	11·5	10·6	4	4·4	4·1	2·3	...
13	1461K.	M. 19	19	6·8	5·3	5	12	11·75	3·8	4·3	4	2·2	132
14	1461H.	F. 19	18·7	6·8	5·3	5	11·75	12·5	3·7	4·3	4	2·4	120
15	L. C. Dub.	Adult	16·5	6·1	3·8	4·4	8·5	8·5	3·7	4	3·9	...	...
16	Do.	Adult	17·5	6·3	4·4	4·5	10	10	3·4	3·7	3·7	2	...
17	Do.	...	17·25	5·8	4·7	4·5	11	10	3·75	4·1	4	2·1	114
18	St Barth.	F. 22	13·5	4·5	3·5	...	6·6	7·3	3·4	3·6	3·5	2·3	...
19	Do.	M. 21	16	5	4	...	7	8	3·6	4·2	4·1	2·6	...
	Averages, .	...	16·7	5·9	4·4	4·5	10·1	10	3·5	4	3·9	2·2	...

MACROCEPHALIC.

No.		Circumf. — Round Glab. and Occip. Spine.	Ant. Post. — Between Glab. and Occ. Spine.	Transverse. — Between Parietal Eminences.	Height. — Front of For. Mag. to Vertex.	Over Vault. — From Glab. to Occ. Spine.	Over Vault. — From one Aud. Meatus to the Other.	Between Apices of Mastoid Process.	Between Margins of Glenoid Fossæ.	Between Outermost Parts of Malar Bones.	Dental Arch. — Between Hinder Parts of Alveolar Process.	Angle of Lower Jaw.
		Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	°
1	Æt. 4, . .	21·75	7	8	8·4	20	22	3·8	4·3	3·8	2	...
	Do. Greatest,(1)	26	8·3	...	...	...	...	...	...	...	...	...
2	Child, . .	20·5	6·5	6·5	6	16	16	..	...	...	...	...
	Do. Greatest,(1)	24·5	8·5	...	...	...	...	...	...	...	...	...
3	8 Months, .	13	4	5·3	4·6	12·5	13·25	1·6	2·1	2·5	1·5	...
	Do. Greatest,(1)	17·5	5·9	...	...	...	...	...	...	...	...	...
4	Under 6 Years,.	18·5	6·1	7	6·5	16	18	3	3·25	3·4	1·5	...
	Do. Greatest,(1)	24·5	7·6	...	...	...	...	...	...	...	...	...
5	M. æt. 43, .	22·5	8·2	6·5	6	14·5	14·25	4·4	5·2	4·75	2·4	120
	Do. Greatest,(1)	24	8·1	...	...	...	...	...	...	...	...	...
6	Romano-British,	23·5	8	6·6	5·7	15·5	15	4·3	5	4·7	2·2	...
	Do. Greatest,(1)	24·75	8·4	...	...	...	...	...	...	...	...	...
7	Do.	23	8	6·8	6·2	16·5	16	4·8	5·4	5	2·5	108
	Do. Greatest,(1)	25	8·75	...	...	...	...	...	...	...	...	...
8	Do.	21·5	7·25	6·75	5·5	15·5	15	4·5	5·3	4·5	2·4	135
	Do. Greatest,(1)	23·5	8·4	...	...	...	...	...	...	...	...	...
9	Do.	22·75	8	7·2	6·2	16	16	4·3	5·25	5	2·8	110
	Do. Greatest,(1)	25·5	8·5	...	...	...	...	...	...	...	...	...
	Average of *first* four,	18·4	5·9	6·7	6·3	16·6	17·3	2·8	3·2	3·2	1·6	...
	Average in Adults,	22·6	7·8	6·7	5·9	15·6	15·2	4·4	5·2	4·7	2·4	118·2

(1) The greatest circumference usually above the level of the glabella and the occipital spine.

AN UNUSUAL MODE AND SITE OF TERMINATION OF THE RIGHT SACRAL SYMPATHETIC CORD. By Edward Fawcett, M.B. Edin., *Professor of Anatomy, University College, Bristol.*

Although many descriptions are given of varieties in connection with the sacral part of the sympathetic cord, these descriptions all refer to the number of ganglia, and not to either the site or mode of termination of that cord. If this case be considered as to its number of ganglia it is distinctly abnormal, for there was only one ganglion present.

Macalister states that there are usually four ganglia present on each cord, and that the cords unite mesially in front of the coccyx in a ganglion impar in 60 per cent. of cases.

Cloquet states that the number of ganglia varies between three and five pairs, and that the two cords terminate in a ganglion impar.

Quain says there are usually five pairs of ganglia.

The other text-books describe either four or five pairs, and all seem to agree in saying that the cords terminate in the region of the coccyx normally.

There is no doubt, then, as to the normal extent of the sacral gangliated cord.

In the case that came under my notice I was only able to examine the condition on the right side, as the left half of the sacrum had been removed by the dissectors of the pelvis in order to expose the right sacral plexus. The right gangliated cord terminated in a thick trunk by entering the anterior face of the *second* sacral nerve, about half an inch from the inner edge of second anterior sacral foramen, and no sign of any continuance beyond that nerve could be made out.

There was one ganglion only present, and that lay on the anterior face of the first sacral nerve.

Such a termination, so far as I know, is unrecorded, and is, I think, of sufficient rarity to deserve noting.

A SKULL WITH ENORMOUS PARIETAL FORAMINA. By Wm. St Clair Symmers, M.B. Aberd.

The skull in question is that of a man aged forty, who died of acute pneumonia.

In each parietal bone is an enormous parietal foramen situated near the posterior superior angle of the bone, and 10 centimetres posterior to the bregma. The ossified sagittal suture runs between the two

foramina, which are about equidistant from the line of synostosis. The bridge of bone between the two foramina (the *obelion* of Broca) is 13 millimetres in breadth.

The foramen in the left parietal bone is oval, with the long diameter lying transversely, its margin is slightly notched internally, and presents externally a minute bony prominence, elsewhere the margin is smooth and rounded, and is distinctly bevelled. The transverse diameter measures 21 millimetres, the vertical 14 millimetres. Immediately internal to this large foramen is a small perforation in the skull, sufficiently large to admit a bristle.

The foramen in the right parietal bone is slightly smaller than that in the left, and is more ovoid in shape; it has bevelled edges and a smooth rounded margin, which is slightly notched internally. The transverse diameter measures 15 millimetres, the vertical 14 millimetres. During life the dura mater was adherent through the foramina to the pericranium, thus forming a tough fibrous membrane, which effectually closed the openings. Through these obturating membranes there passed several minute emissary veins.

On inquiry it was found that the father of this man had a similar abnormality of the skull.

ADVENTITIOUS JOINT OF THE FEMUR FOLLOWING UN-UNITED FRACTURE. By Gordon Sharp, M.B.

A boy of 13 was knocked down in the football field, and sustained a simple fracture of the middle third of the femur. He was seen in an hour or two by a doctor, who fixed up the fractured limb in a modification of Liston's long splint. At the end of six or seven weeks he was sent into an hospital in Lancashire suffering from un-united fracture, where he came under my notice.

The fracture, which at first was simple, had become compound, and there was a long sinus leading to the fractured ends of bone. The boy had come from a densely populated, squalid quarter of the town. He was covered with lice; ulcers were present on the foot and ankle of the whole limb, and both legs bore marks of hæmorrhages under the skin. He had had little food, and that bad in quality. It was found to be impossible to save the limb, hence amputation was carried out.

On examining the fractured bone, the upper fragment was found to be cup-like, smooth, and filled with a gelatinous fluid. On careful inspection small points of blood could be seen here and there. A thin scraping from the cup-like depression was placed under the microscope, and found to be made up of new bone, osteoclasts, and collections of red-blood corpuscles. On looking at the cut end of this upper fragment, the new bone is seen encircling the old bone. The lower fragment is rough at its upper end; and although much new bone has

been formed, there has not been enough to ensheath the upper fragment. Instead of being round at its upper end, as one would have expected, it is irregular. This is to be accounted for by its poor blood-supply compared with the upper fragment.

In tracing the pathological condition one finds that the boy was knocked down when in a condition of health in which his bones readily gave way. Nature did her best to repair the injury. Ensheathing callus was formed by the upper end, but not by the lower end, or if formed, was soon broken down again. Nature, baffled in this attempt, does the best she can, and forms the lower end of the upper fragment into a smooth cup-like depression, containing a gelatinous-like fluid. The upper end of the lower fragment, however, is not transformed to fit into this, and the effort of nature has not been fully effected. This case illustrates the influence of mal-nutrition on the healing of tissues, and the great effort which nature makes to overcome difficulties.

Notices of New Books.

Crania Helvetica Antiqua. By Prof. Th. Studer and Dr E. Bannwarth. Leipzig: J. A. Barth, 1894.

In this work Drs Studer and Bannwarth have given a description, and have illustrated with 117 figures, the human crania which have been found in the pile-dwellings in Switzerland, and which have been regarded as belonging to the people of the Stone and Bronze Periods. These crania are believed to be the oldest human remains which have been found in Switzerland. The Swiss Stone Period may be divided into two epochs:—*a*, in which the implements consisted only of stone, bone, and horn; *b*, where implements formed of copper, or containing a large proportion of copper, were found in small numbers along with those made of stone and bone. In the Bronze Period, the weapons and implements consisted for the most part of bronze.

Thirty-five crania have been reproduced in the plates which illustrate the work. Two distinct types were recognised, a dolicho-cephalic and a brachy-cephalic, which differed from each other not only in the numerical indices, but in the form and character of the brain-case and of the face. In the brachy-cephali, the length-breadth index ranged from 79 to 84. The forehead was broad and low; the vertex was usually flattened, though somewhat elevated in the middle line; the parietal eminences were strongly projecting, and the contour was angular, owing to this projection. The back of the sagittal region was flattened, the jaws were somewhat prognathous.

The dolicho-cephali ranged from 67·9 to 76 in the length-breadth index. The forehead was narrower and higher. The parietal curve was long and uniformly arched; the sagittal region was slightly elevated, the occiput long and full; the whole cranium in the norma verticalis being a long oval. The jaws were mostly orthognathic, though individuals were slightly prognathic.

Of fifteen crania referred to the brachy-cephalic type, thirteen belonged to the Stone Period, both in its older and later stage, and only two to that of Bronze. Twenty-one skulls were distinctly dolicho-cephalic, and of these eight belonged to the later stage of the Stone Period, whilst twelve or thirteen were of the Bronze Age; eleven other skulls had meso-cephalic proportions, and of these four were of the later stage of the Stone Period and seven of the Bronze Age. From this statistic it would seem as if the brachy-cephalic type is older than the dolicho-cephalic, for the long heads are wanting in the earlier period of the Stone Age. The authors consider that the crania of the Bronze Period found in the pile-dwellings are those of the proper inhabitants of these dwellings. As regards the crania of the Stone

Period there is more difficulty; and it is possible that the dolichocephalic skulls are not those of the proper inhabitants, but of migratory people employed as workers.

Anatomie des Centres Nerveux. By Dr J. Dejerine and Madame Dejerine-Klumpke. 1st Volume. Paris: Rueff & Co., 1895.

This is an elaborate and beautifully illustrated volume on the anatomy of the nerve centres. The first part treats of the methods to be employed in the study of the central organs; of the development of the nervous system; of its histogenesis; and of its general histology in the adult. The second part comprises the anatomy of the brain, its general morphology, including both its external and internal configuration; its topography; its microscopic texture, including the structure of the cerebral cortex and the rhinencephalon; and the arrangement of the white matter, as regards both the association and the commissural fibres.

This work is not a mere compilation, but is the result of many years of labour on the part of Professor and Madame Dejerine. The material which they had collected has been in part obtained from the Hôpital de Bicêtre. In a great number of cases the results furnished by normal anatomy have been controlled by the study of secondary degenerations, so that the work embodies much pathological material, and appeals both to the physician and the anatomist.

The authors have largely used the methods of Weigert and Golgi in the study of the histological characters; but that which gives especial value to their work is the employment of serial sections through the brain, both macroscopic and microscopic, and the reproduction of these sections, in the first instance by photography, and, in the book itself, by a beautiful series of illustrations, prepared by M. Gillet. These sections have been made in three planes, horizontally, verticotransversely, and sagittally; and they furnish a definite picture of the relations of the cortex of the brain to the deeper parts, and of these latter with each other, more fully and precisely than in any other treatise on the anatomy of the brain with which we are acquainted. It is especially to be noticed that these illustrations are not schemes, more or less hypothetical, but reproductions of actual sections.

In the chapter on the structure of the cerebral cortex, the writings of Gustav Retzius and Ramon Y. Cajal have been consulted, and many of their drawings of the arrangement of the nerve cells, stained by the method of Golgi, have been reproduced. The structure of the cornu ammonis and of the fascia dentata is illustrated with a number of figures.

The last chapter, on the association and commissural fibres of the white matter, treats of a branch of cerebral anatomy, the study of which presents many difficulties, more especially in the human brain, where the fibres cross each other and seem to be inextricably intermingled. Four sets of fibres are described with much detail:—

(1) *association* fibres, which connect two regions of the cerebral cortex more or less separated from each other; (2) *commissural* fibres, which connect opposite hemispheres; (3) *projection* fibres, which connect the cortex cerebri to the central and other ganglia, as low down as the spinal cord; (4) *centripetal* or *terminal* fibres, which comprise, (*a*) fibres that arise in one cortical region and end in an arborescent manner in another, and (*b*) fibres arising in other regions than that of the cortex, *e.g.*, optic thalami, cerebellum, which also end in the grey substance of the cortex in free arborisations.

The whole conception of this treatise on cerebral anatomy, and the mode in which the complicated details of brain structure have been worked out and illustrated by Dr and Madame Dejerine, are such as to give to their treatise a high place in anatomical literature, so that it will need to be carefully studied by all other workers in this fruitful field of scientific research.

Die Äusseren Kiemen der Wirbeltiere. By P. Clemens. Wiesbaden: J. F. Bergmann, 1894.

This memoir is an enquiry into the external gills of vertebrates, conducted under the auspices of Professor Wiedersheim, in the Anatomical Institute of Freiburg. The descriptions are illustrated with thirty-four figures. The general conclusions arrived at are as follows:—Some gills are rod-like and unbranched, as in Hylodes, Pipa, Dactylethra, Hyla? Others are branched. In one group of the branched gills the principal stem projects slightly, has no special muscles, and its epithelium is ciliated; in Rana, Bufo, Cystignathus, and, indeed, most Anura, the gill threads spring from the ventral side of the main stem, and the hindmost gill is the shortest; in Derotrema and Cæciliidæ the gill threads are symmetrical on both sides of the main stem; sometimes the most anterior, sometimes the middlemost, is the longest. In a second group, the Salamandroidæ, the main stem projects as the body of the gill; it has special muscles; the epithelium is not ciliated; the hindmost gill is the longest. In certain members of the second group the body of the gill is not branched; in some, as Triton, Desmognathus, Ochrophæa, Gynnophilus, *Salamandra maculata* ii., Spelerpes, Pelonectes, Chondrotus, Axolotl ii., and Menobranchus, it is wedge-shaped; in Polypterus, Protopterus, *S. atra* and *maculata* i., it is more flat and leaf-like. In others of the second group the body of the gill is branched; in *Pseudobranchus striatus* the gill body is simple, and only the anterior outer border is branched; in *Siren lacertina* ii. and Calamoichthys both borders are branched; in Proteus and *Siren lacertina* i. the gill body is doubled and branched. The outer gills of Dipnoi and Amphibians are ektodermal, pigmented, with a cubical ciliated epithelium, and only dorsally attached to the convexity of the gill arches. The inner gills of Fishes and Anura are entodermal, not pigmented, with flat, non-ciliated epithelium (*abgesehen von Amphioxus*), and attached to the whole broad side of the gill arches.

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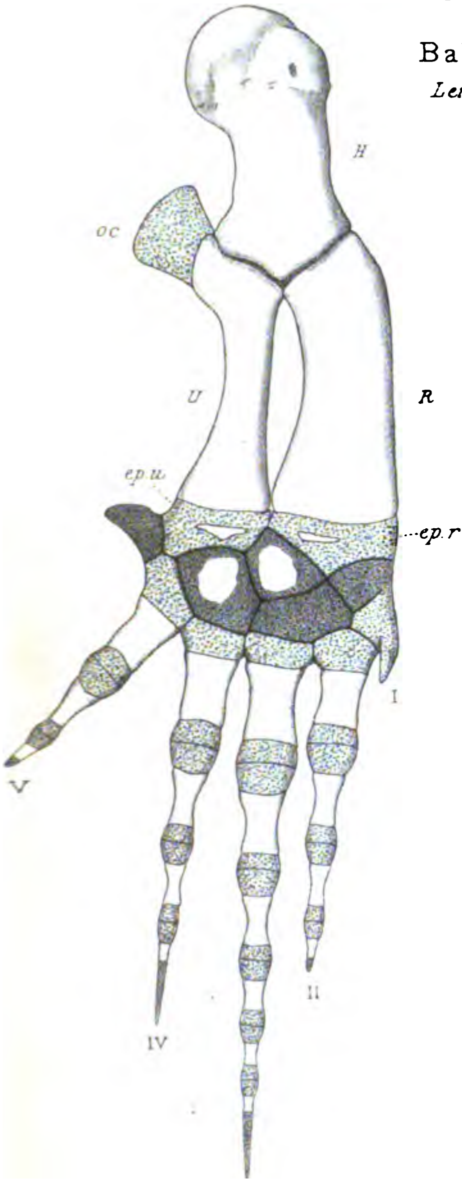
Fig. 1.

Fig. 1. Pectoral Limb
of 48-feet-long
Balaena mysticetus.
Left side. Palmar surface



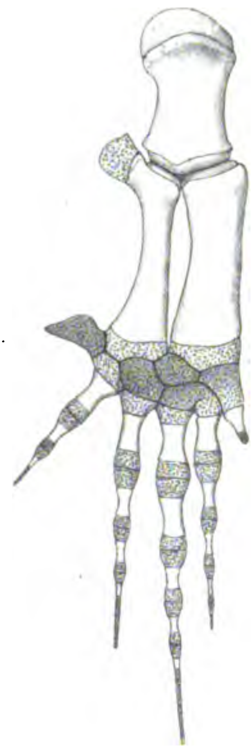


Fig. 2.

Pectoral Limb
of 35-feet-long
Balaena mysticetus.
Right side. Dorsal surface.

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GREENLAND RIGHT-WHALE. BALAENA MYSTICETUS.

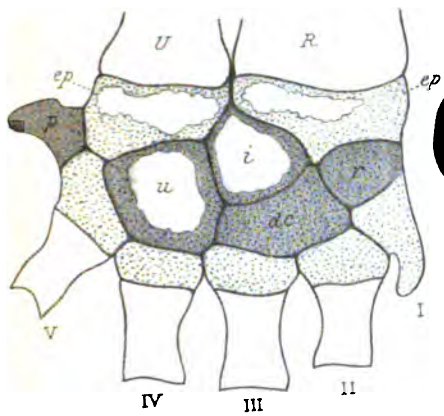

Fig. 3.

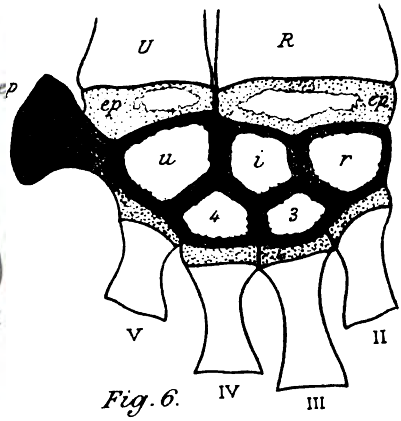

Fig. 6.

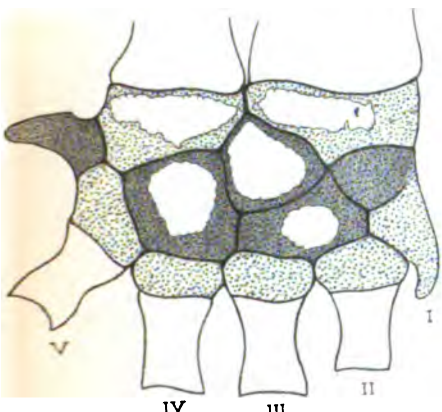

Fig. 4.

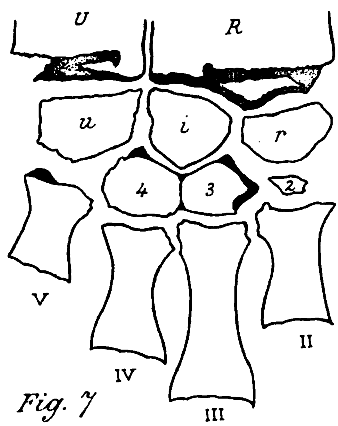

Fig. 7

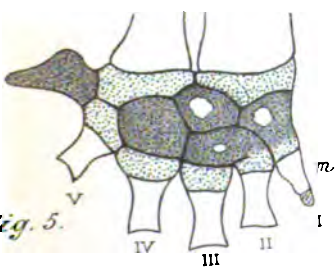

Fig. 5.

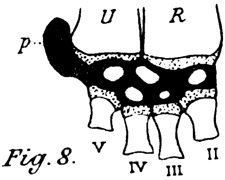

Fig. 8.

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Fig^s. 3, 4 & 5, Mysticetus.

Fig^s. 6 & 7, B. musculus.
Fig. 8, B. rostrata.

CARPUS OF MYSTICETUS AND FIN-WHALES.

Fig. 9.

Fig. 9. B. Mysticetus
50-feet-long.
From a Drawing by
CAPTAIN DAVID GRAY,
of the "ECLIPSE,"
PETERHEAD.

Fig. 10.

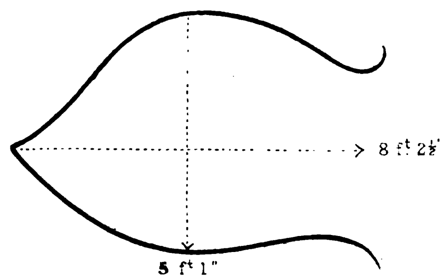

Fig. 10. Pectoral Limb
of B. Mysticetus,
seen on the face (palmar.)
From a drawing by
Dr ROBERT GRAY.

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F Huth, Lithr Edinr

GREENLAND RIGHT-WHALE. BALAENA MYSTICETUS.

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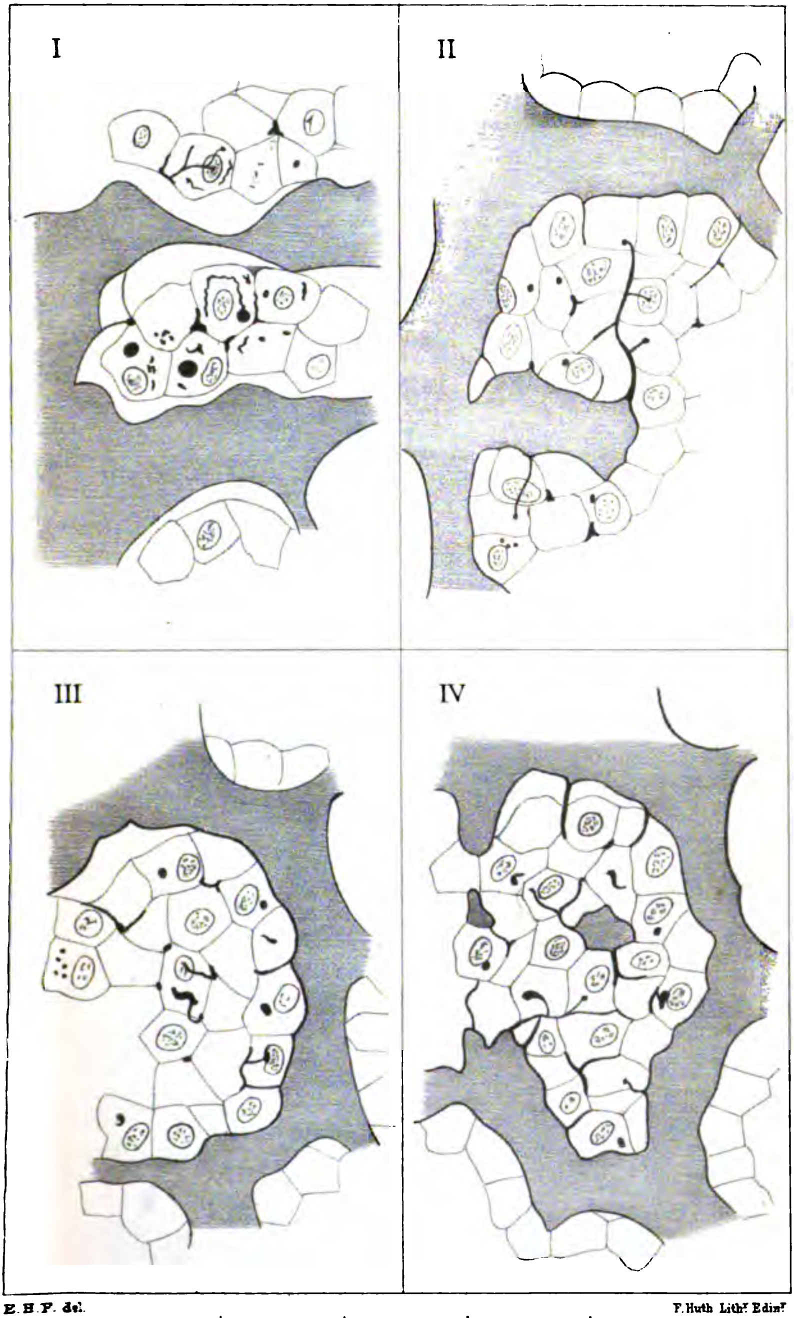


E. H. P. del.

F. Huth Lith.r Edin.r

Scale .001 inch.

LIVER OF FROG.

Journal of Anatomy and Physiology.

VARIATIONS IN CRANIA OF *GORILLA SAVAGEI*. By W. LAURENCE HENRY DUCKWORTH, Fellow of Jesus College, Cambridge.

THE following account results from observations made on more than one hundred skulls of the gorilla. The actual number of specimens available for establishing the desired facts was 109, and these are distributed among several museums in this country and in France, a list of which is appended.

The observations are recorded in tabular form for facility of reference, and in the following paragraphs the results of an examination of these tables are presented, and in some cases commented upon.

Classified according to *sex*, 62 skulls are those of adult or aged males, 38 of adult or aged females, 13 of immature individuals.

With regard to observations on the prominence of the bony crests of the cranium, in about half the number of female skulls there is coalescence of the temporal ridges to form a sagittal crest of small dimensions: in some skulls of adult females an arrangement of alternate ridges and furrows is seen in the region of the sagittal suture: in five cases three such ridges with intervening furrows are noticed.

In the skulls of adult males there is in every case a sagittal ridge, varying considerably in height in different individuals: three degrees can be recognised, viz., crests of about 20, 30, and 40 to 45 mm. in height respectively. Specimens are evenly distributed among these three classes, but rather fewer occur in the last, *i.e.* where the crests exceed 40 mm. in maximum height.

The height of these sagittal crests does not depend on age, for, in some specimens with clean and little-worn teeth, the crest is

developed to an exaggerated extent, while in some evidently aged specimens the height is not nearly so great. In one case of an old male this crest is involved in a general pathological process affecting most of the cranium.

With regard to other bony prominences, large mastoid processes occur in one case only; infra-temporal crests are, as a rule, small and oblique in direction, and are in no case produced into such spurs or spiny processes as often occur in human crania. Figures represent the relative extent of development of the tuber maxillare in the two sexes, in neither of which was it at all usual to meet with such a comparatively large tuber maxillare as commonly in certain human races contributes considerably to the palate length. A large tubercle directed downwards from the malar bone is seen in three male specimens, being probably connected with the size and extensive origin of the masseter muscle. Further correlations of a similar kind are noticed where the ascending ramus of the mandible attains considerable width, as in three males, measuring respectively 80, 77, 76 mm. across, while in two other cases the angles of the mandible are much everted.

Again, the genial tubercle is not unfrequently represented by a sharp ridge in adults of either sex, though in several it is absent, or replaced by a depression. A styloid process was not observed in any of 94 specimens examined with regard to this feature: a frontal exostosis behind the supra-orbital crest and between the converging temporal crests, of a female specimen, is worth notice; while the Eustachian processes on the petrous bones (whose axes are nearly parallel) vary a good deal in shape, being perforated in three cases, bifid in two others.

The observations on the conformation of the region of the foramen magnum may thus be summarised: in one case only was there a distinct trace of a third occipital condyle, so that this feature is very rare; in one case only was there an approach to a patent post-condylar foramen: the condyles present a good deal of variety in size and position,—prominent, oval, and everted or depressed, round, and small forms occur with almost equal frequency; cases occur (*a*) where a transverse groove interrupts each condyle; (*b*) where an almost longitudinal ridge modified the articular surface; and also (*c*) in which prolongations are

sent off either anteriorly or posteriorly, the form of the foramen magnum being correspondingly modified. (Where a groove interrupts the articular surface, the reason for its presence may be imperfect coalescence of the parts of the condyles formed from the ex-occipitals with those formed from the basi-occipital.)

Passing to the region of the pterygoid plates, one may notice that the external plate is usually small, and not very strongly everted; that a fossa on the external surface of the external pterygoid plate, or a ridge (called pre-pterygoid) bounding such a fossa anteriorly, are both of rare occurrence. A pterygo-spinous foramen is of more frequent occurrence. Further cases are noticed wherein sharp spurs project outwards from the free edge of the external plate; where the hamulus of the internal plate attains considerable size; where the hamulus is represented by a quadrate mass; where the scaphoid fossa is prolonged down the internal pterygoid plate to the hamulus.

The disposition of parts in the posterior region of the hard palate is subject to a good deal of variation, there being a considerable number of varieties, often attributable to the frequent lack of union between the palatine processes of the palate bones. They may be conveniently classified with regard to the presence or absence of a posterior palate spine. The results of observations on 105 specimens show that an indication of such a spine is met with in one only out of every three cases. The disposition of the vomer with regard to the palate bones also offers some interesting varieties: thus, in four cases it appears in the hindmost portion of the median suture of the hard palate, and is there embraced by the palatine processes of the bones of that name; in other cases (six in number) the palate bones still do not meet, but are separated by processes of the maxillæ, and not by the vomer. In the situation of the anterior nasal spine of Man, small tubercles are seen in four cases on the facial surface of the premaxillary bones. The question whether such tubercles really represent the anterior nasal spine of Man is rendered difficult by the fact that in about 36 other cases (young individuals being in a majority) a sharp spine is directed backwards from the posterior or intranarial surface of each premaxillary bone, and comes into contact in many cases with the vomer. It is suggested that such are indeed true anterior nasal spines, which,

owing to the great size of the incisor teeth, and the consequent swollen condition and larger dimension of the premaxilla in the gorilla, do not asume the prominent and conspicuous position that they occupy in Man. In this connection it may be remarked that the nasal spine is a feature of the infant human skull, and that the latter in this respect differs from skulls of either young or adult gorillas quite as much as does the adult human skull. It would be interesting to observe stages between the backward and forward direction of this anterior nasal spine in gorilla and Man.

The infra-orbital margins are, as a rule, much bevelled off; in one or two cases, however, they are quite sharp in adults, though this seems a persistence of a feature of adolescence. In no case among 102 specimens examined did a hamulus lacrymalis project over the orbital margin on to the facial surface.

Of the teeth it may be remarked that the second lower bicuspids are usually quadrituberculate: six cusps are sometimes seen in true molars; one skull has acquired all the teeth of the permanent set, with the sole exception of the canines, whose places are still occupied by their feeble "milk" representatives. In another case five upper incisors are seen. In two examples an additional molar tooth is present (in both on one side, and in one jaw only), making six teeth posterior to the canine. The two upper rows of post-canine teeth present varying degrees of convergence towards one or other extremity of the palate.

With regard to the cranial sutures, it may be remarked that besides the early synostosis of the components of the occipital and malar bones, that of the two nasal bones is fairly constant in its occurrence. On the other hand are cases where sutures remain open to a later period than might be expected. In two skulls (both of females) is this the case with the coronal suture: more notably is it the case with the spheno-basilar suture, which was frequently found still unclosed in specimens otherwise evincing signs of a fully adult condition (of this there are 13 examples, mostly of male skulls): in one case an ossicle was situated in the still unclosed suture.

Of such ossicles in sutures examples are not rare, more

especially in young specimens; the usual situations being the lambdoid suture, the region of the lacrymo-ethmoid suture and the Glaserian fissure. Of the region of the lacrymo-ethmoid suture, it must be said that it is more usual to find the frontal and superior maxillary interposed between the lacrymal and ethmoid bones, than to find a lacrymo-ethmoidal suture.

On one occasion only was there seen a spheno-maxillary suture cutting off the malar bone from the spheno-maxillary fossa. An infra-orbital suture on the facial surface (pars facialis) is not uncommon, and the infra-orbital canal on the orbit is less completely roofed in than in Man. A table represents the data with regard to the conformation of the pterion region: in one case (on one side, and in a young specimen) was a spheno-parietal suture met with at this point. Hartmann (*Der Gorilla*, Taf. xix. 2*a*) represents a similar conformation in the skull of an adult male.

Of foramina the following notes were made:—The foramina spinosum, Vesalii, and lacerum anterius are of inconstant and rare occurrence. In one specimen intracranial appearances indicate that the middle meningeal artery passed through the foramen ovale, even though a foramen spinosum is present. Obelial foramina (10 examples) often pierced the sagittal crest, without, however, penetrating to the interior of the cranium. The olfactory foramina in the cribriform plate of the ethmoid seem to be usually disposed in two ranks. The number of the infra-orbital foramina on each side is subject, as the table shows, to considerable variation. The arrangement of the anterior palatine foramen suggests that in the broadly expanded palate of the gorilla, the foramina of Scarpa and Stenson are not, as in Man, crowded together into one depression, but that the former two occupy the middle line, while the two latter occupy lateral positions somewhat removed from that region. The presence of a depression, sometimes so deep as to be called a foramen on the exterior of the basi-occipital bone, was of not uncommon occurrence; possibly it replaces the pharyngeal spine, though such a depression not unfrequently occurs in human crania.

The concluding remarks refer to the skeletons generally, and to certain pathological features. Of the former, the occurrence

of a defective posterior arch of the atlas in an adult female, and of fourteen ribs in a young specimen (at Le Havre), are noteworthy; in the skeleton of an adult male of very great size at Liverpool, the last lumbar vertebra is ankylosed with the sacrum on one side; in an adult male skeleton at South Kensington the right olecranon fossa is perforated.

Of skeletons of 25 individuals examined, 6 (24 per cent.) were affected by some pathological process. Of these, the skeleton of a large adult male (presented by Henry Duckworth, Esq., to the Brown Museum, Liverpool) shows signs of extensive disease, probably rheumatic in nature, in the left condyle of the jaw and glenoid fossa of that side. A skeleton in the Museum of the Société d'Anthropologie at Paris gives evidence of much widespread necrosis of the skull, especially of the left side of the face in the region of the orbital margins; the left scapula is also affected, and its squamous part perforated. The specimen presented by Franquet, at the Jardin des Plantes, shows extensive necrosis of the face in the region of the left upper canine tooth especially (and one humerus is much shortened). In a specimen at South Kensington ulceration has occurred near the base of the socket of the left lower canine tooth, leaving a fistulous passage between this and the exterior of the bone, being probably associated with dental caries. The same condition obtains in a second specimen at Kensington, in addition to extensive necrosis of the left humerus. Of other skulls affected by morbid processes, those are most common in which ulcerative disease has occurred near the roots of the canine teeth; examples are also met with of disease over the antrum on the face, on the external angular process of the frontal bone, on the hard palate, and in the nasal fossæ.

General Summary.

The foregoing observations were made in the first instance with a view to establishing the frequency and prominence in skulls of gorilla of features which, when met with in human skulls, are sometimes said to indicate a "simian" type. And indeed such conformations seem to occur with greater frequency in skulls of certain of the "lower" human than in the

"higher" human races. With regard to such points, a general review seems to show that of the peculiarities of skulls of "low" human races, not so many are "simian" as might be expected. But here it must be remarked that such observations ought to be extended to crania of other members of the family of anthropoid apes. Having regard to this, it is suggested that the following are decidedly *gorilla-like* features of the skull of a member of a "low" human race, viz.:—

(1.) Fronto-squamous suture at pterion.
(2.) Fronto-maxillary suture in orbit.
(3.) Early and complete closure of foramen lacerum anterius.
(4.) Absence of vesalian and post-condylar foramina.
(5.) Diminutive posterior palatine spine.
(6.) Diminutive styloid process.
(7.) Flattened outline of squamous portion of temporal bone.

Whereas the following features, in which skulls of a "lower" human race differ from those of a "higher" race, are not points which approximate them to the crania of gorilla:—

(1.) Sphenoid contribution to glenoid fossa.
(2.) Large tuber maxillare.
(3.) Third occipital condyle.
(4.) Trace in adult of suture dividing occipital squama from ex-occipitals.
(5.) Spheno-maxillary articulation outside the orbit cutting off the malar bone from the spheno-maxillary fossa.
(6.) External-pterygoid fossæ, pre-pterygoid ridge.
(7.) Large and spiny infra-temporal crests.

The last (6 and 7) sets of features are worthy of remark. Though in the gorilla the glenoid fossa is large and flattened, and thus adapted to movements of mastication, yet the presence of an immense "endo-glenoid" tubercle prevents lateral movements. In correlation with which is the fact of the small degree of development of the infra-temporal crests and external pterygoid plates. In further correlation with movements of the mandible is the conformation of the region of the spine of the sphenoid, in the gorilla much developed, so that the position of the foramen ovale relative to the petro-sphenoidal fissure (which is deter-

mined by it) is seen to differ from that in Man, in whom the interval between the two is relatively less than in the gorilla. Man in this respect occupies a position intermediate between the orang and gorilla; the arrangement in the former being approached by that in the young gorilla.

In conclusion, very hearty thanks are expressed to those who have permitted examination of the specimens under their charge.

The Museums visited are the following:—

			Director.
Cambridge University, .	3 Skulls,		Mr Harmer.
Liverpool Museum, .	10 Skulls,		Dr Forbes.
Musée du Havre, France, .	12 Skulls,		Dr Lennier.
L'École d'Anthropologie, .	10 Skulls,	Paris,	Prof. Hervé.
La Société d'Anthropologie,	15 Skulls,	Paris,	Prof. Hervé.
Laboratoire Broca, . .	3 Skulls,	Paris,	Dr Manouvrier.
Jardin des Plantes, . .	28 Skulls,	Paris,	Prof. Milne-Edwards.
British Museum, S. Kensington, . . .	8 Skulls,		Sir W. H. Flower.
Royal College of Surgeons,	12 Skulls,		Prof. Stewart.
Oxford University, . .	7 Skulls,		Prof. Tylor.
	108 Skulls.		

Casts of 4 skulls from the City Museum, Bristol, and a skull in the possession of Mr Chas. Jamrach, were also examined.

TABLE I.

Character.	No. examined.	Mode of Occurrence.
Sagittal crest	78	Adult or aged males—small crests, 19 ; large, 22 ; very large, 16. Females—small crests, 18 ; no crests, 3.
Styloid process	94	Did not occur.
Pterygo-spinous foramen .	...	Present in 6 males (a trace in another male) ; both sides in two cases ; present in 6 females.
Hamulus lacrymalis . .	102	In no case projected over the orbital margin.
No. of post-canine teeth .	80	Additional molar in 2 males only ; 51 males, 29 females examined.
Trace of division of occipital bone	98	Occurred in 6 out of 7 young examined ; no occurrence in 56 adult males or 29 adult females.
Trace of division of malar bone	104	Did not occur. Of the 104, 13 are young specimens.
Anterior nasal spine . .	72	Traces seen in 36 examples (15 males, 13 females, 8 young).
Sphenoid contribution to glenoid fossa	95	Did not occur.
Foramen vesalii	101	A trace seen on one side, and once only.
Foramen post condylare .	84	A trace seen once only.
Foramen lacerum anterius .	93	Closed in all except one young specimen.
Spheno-maxillary suture outside orbit	95	Occurred once, on left side only.

TABLE I.—*Sheet* 2.

Character.	No. examined.		Mode of Occurrence.	No. by Sex.
Infra-temporal crests	102	Males	Insignificant, 15 ; small, 30 ; prominent, 14	
		Females	Insignificant, 9 ; small, 15 ; prominent, 10	
		Young	Insignificant, 12	
Tuber maxillare	102	Males	Absent, 2 ; insignificant, 13 ; moderate, 40 ; large, 5	60
		Females	Absent, 17 ; insignificant, 9 ; moderate, 7 ; large, 0	33
		Young	Absent, 4 ; insignificant, 5 ; moderate, 0 ; large, 0	9
Genial tubercle	78	Males	Depression, 12 ; flattened surface, 6 ; ridge, 28	
		Females	Depression, 6 ; flattened surface, 3 ; ridge, 13	
		Young	Depression, 0 ; flattened surface, 2 ; ridge, 8	
External pterygoid plates	95	Males	Much everted, 31 ; moderately everted, 24	55
		Females	Much everted, 16 ; moderately everted, 15	31
		Young	Much everted, 7 ; moderately everted, 2	9
External fossa	105	Males	Insignificant, 55 ; noticeable, 5	
Pre-pterygoid ridge	105	Females	Insignificant, 29 ; noticeable, 2	
		Young	Insignificant, 10 ; noticeable, 1	
Posterior palatine spine	105	Males	Type A. 10. Type B. 19. Type C. 30	59
		Females	Type A. 6. Type B. 13. Type C. 16	35
		Young	Type A. 4. Type B. 2. Type C. 5	11

TABLE I.—*Sheet* 3.

Character.	No. examined.		Mode of Occurrence.	No. by Sex.
Lacrymo-ethmoid suture	Open in 53		Length: Lacrymo-ethmoid. / Fronto-maxillary.	
		Males	9. 17. R. 4 (6), L. 4 (4) . 8 (9), 5 (10)—	
		Females	6. Fronto-maxillary 7. R. 5·5 (4), L. 3 (4) . 5 (4), 4·5 (2)—	
		Young	4. 10. R. 2, L. 4 . 3 (2), 5 (5)—	
Pterion region . . (Length of fronto-squamous suture)	77	Males	R. 18 (13), L. 19 (14)—	
		Females	R. 17 (3), L. 15 (4)—	
		Young	R. 15 (18), L. 16 (16) (young adults here included).	
Foramen spinosum .	97	Males	Present on both sides, 24 ; present on one side, 17 ; absent, 15	56
		Females	Present on both sides, 17 ; present on one side, 5 ; absent, 9	31
		Young	Present on both sides, 7 ; present on one side, 1 ; absent, 2	10
Infra-orbital suture .	106	Males	Closed, 49 ; open partially, 10	59
		Females	Closed, 33 ; open partially, 2	35
		Young	Closed, 4 ; open partially, 8	12
Infra-orbital canal .	108	Males	Open about *half-way* throughout orbit, 28 ; open nearly throughout orbit, 26	
		Females	Open about *half-way* throughout orbit, 15 ; open nearly throughout orbit, 17	
		Young	Open about *half-way* throughout orbit, 3 ; open nearly throughout orbit, 9	
Infra-orbital foramina (with data from Hartmann)	111	...	One on right, 58 (78 H.) ; two on right, 51 (56 H.) ; three on right, 2	
	136	...	One on left, 61 (77 H.) ; two on left, 42 (51 H.) ; three on left, 7 (H. indicates that the specimens figured by Hartmann are included.)	

Figures in brackets indicate the number of examples whence average length is calculated.

ON THE EFFECTS OF ELECTRICITY AND MAGNETISM ON DEVELOPMENT. By BERTRAM C. A. WINDLE, D.Sc., M.D., M.A., *Professor of Anatomy in Mason College, Birmingham.*

IN a former paper in this *Journal*[1] I detailed briefly the results which I had obtained from passing a small constant current through hens' eggs during the process of incubation. I propose to describe in this communication some further experiments of a similar nature conducted with hens' eggs, and with trout and silkworm ova.

I. INFLUENCE OF MAGNETISM ON THE DEVELOPMENT OF HENS' EGGS.

In the first series of experiments in this direction I placed the eggs, twelve in number, between two small bar magnets (1·9 × 0·6 cm. at poles). Temperature and other conditions in this, as in all the other experiments, save where the contrary is indicated, were normal. Of these twelve eggs, four were placed between the magnets, a second group of the same number alongside of one of them, and a third on the other side of the second group, thus at some little distance from the magnet itself. When examined on the fourteenth day, of the first four all had developed normally with this exception, that one of them had an extra toe on each foot,—too common an abnormality, however, to be set down to the score of the magnet. Of the second four, three had developed normally, and in the remaining egg there was only a small dead embryo. In the third four, the group furthest from the magnets, one was normally developed, one had not developed at all; the remaining two shells contained small dead embryos.

The magnets used in this experiment being of small power, I thought it better to substitute on future occasions a more powerful instrument, and in the remaining experiments I used a horseshoe magnet of the largest size capable of being placed in my incubator. The poles of this instrument, 4·7 × 1·3 cm. in

[1] "On certain early Malformations of the Embryo," vol. xxvii. p. 436.

size and 1·0 cm. apart, were capable of sustaining a weight of eight pounds. The eggs were grouped as closely around the poles of the magnet as possible, six being introduced at a time on five occasions, and twelve on two. Of the fifty-four eggs thus experimented upon, twelve showed no sign of development whatsoever, being probably unfertilised, and nineteen were, at the time of their examination, of normal size and appearance for their age. The remaining twenty-three presented obvious abnormalities, of which with one exception all belonged to the class of early malformations associated with deficient development of the area vasculosa. In some of these cases the sinus terminalis was represented by a wide ring of closely opposed dots, in the centre of which were to be seen scanty collections of blood-islands and streaky vessels, a few of which at times appeared to connect with the interior of the embryo, though more often there was no obvious connection between the latter and the external vascular system.

In other cases the sinus terminalis was only represented by a crescent-like arrangement of apparently uncommunicating dots, situated at one side or other of the egg, the internal appearances being similar to those just mentioned, but usually confined almost exclusively to the side where the crescent lay. In all these cases the embryo in the centre was small, generally contorted or otherwise deformed, dead, sometimes œdematous, sometimes partially macerated. In the one exception there was also an imperfect area vasculosa formation, that structure being large in circumference, but very irregularly formed internally. The body of the embryo was, however, hyperæmic,—in fact, engorged with blood, especially on its left side, on which it in part lay. The allantois in this case was well developed and vascularised.

It should be mentioned, that in these experiments there was, so far as I could ascertain,—and I directed especial attention to this point,—no relation between the position of the eggs with regard to the poles of the magnet and the fate of the contained embryo. That the number of abnormally developed embryos was unduly large in these experiments is obvious, but I am not prepared to go further than this statement in associating the condition with the magnetic field in which it was produced. I

will therefore content myself with simply recording the results which I have obtained, as a contribution to the now rapidly growing literature of artificial teratogeny. In this connection it may perhaps be well to briefly summarise the results of the only other experiments of the kind with which I am acquainted, diverse as they are from those obtained by me. Maggiorani,[1] during the process of artificial incubation, exposed a number of eggs to the action of powerful magnets. A similar set of eggs were hatched in same manner, but apart from the magnetic influence, as controls. Cases of arrested development were four times more numerous in the first group than in the second. Microscopical examination showed that the arrest was probably due to an intense vascularisation of the yolk-sac. (This observation is curiously opposite to mine.) After the hatching out of the chicks, the mortality in the magnetic group was three times greater than that of the normal. All the control chicks reached their full development, whilst of the 114 of the first group 60 presented notable imperfections. Their movements were also abnormal, and there were three cases of paralysis and two of contractions. Six of the chickens arrived at maturity. Of these, two were cocks of a splendid stature, and endowed with an insatiable reproductive appetite. With the four pullets it was quite the contrary. One of them never laid at all, and the three others generally produced merely minute eggs, without yolks or germinal spots.

II. Influence of Magnetism on the Development of Silkworms.

Some years ago I was much interested in reading the results of some experiments made by Mr Slater[2] in connection with the development of caterpillars under the influence of magnets. He placed three caterpillars of the common large white (cabbage) butterfly in a box between the poles of two bar magnets. Three others of the same brood were placed in a similar box, but apart from the magnetic influence. Both boxes were placed under

[1] *Atti. R. Acc. d. Lincei*, viii. (1884) p. 274 (Abstr. in *Jl. Roy. Microsc. Soc.* iv. 861).

[2] *Trans. Entom. Soc. Lond.*, 1885 (Abstr. in *Jl. Roy. Microsc. Soc.*, v. 988).

exactly identical conditions as regards light, heat, and supply of food. Two of the caterpillars between the magnets shrivelled up and died without passing into the pupa state. Thinking that they might have been attacked by some parasite, the observer removed them into another box and kept them for some time. As no ichneumons or other parasites made their appearance he dissected the bodies carefully under the microscope, and found no traces of parasitic injury. The remaining caterpillar, and all the three which had not been exposed to the magnets, became pupæ in due course and came out in May. The non-magnetised ones were perfectly normal and healthy, and when released after examination flew away, but the survivor of the magnetised set was a cripple. It had merely rudimentary stumps in place of antennæ, the wings on the left side were expanded, and the legs on the same side were smaller than on the right. As it seemed to me that the number of caterpillars used by Mr Slater was far too small for purposes of generalisation, I determined to repeat the experiment with much larger numbers, and I selected silkworms for my purpose because there is no difficulty in procuring them in any quantity, and their method of development is, of course, perfectly familiar to everybody. I placed, therefore, one hundred silkworms, of the smallest size at which they can well be purchased, in a tray, which was suspended immediately above the poles of a large horseshoe magnet. As I was not circumscribed by space as in the previous experiments, I used a much larger instrument, having poles $7{\cdot}2 \times 2{\cdot}5$ cm. and $3{\cdot}0$ cm. apart, and capable of supporting a weight of twenty-two pounds. With the aid of a compass it was easy to show that the entire of the tray was well within the magnetic field. One hundred other silkworms belonging to the same brood were placed in a similar tray and in the same room, but outside the field of the magnet. The occupants of both trays were fed with mulberry leaves, and treated in every way as regards light, air, &c., identically. In the process of time the occupants of both trays became fewer from deaths and accidents, but eventually exactly the same number from each, viz. forty-two, spun. From the cocoons there emerged of the magnetic lot thirty-six, being twenty-one males and fifteen females; of the non-magnetic, thirty-three, being seventeen males and sixteen females. In each batch there was

one abnormal moth, that of the magnetic group being a male, with very small crumpled wings, and that of the non-magnetic, also a male, having the wings of the left side about half the size of those of the right. It is quite obvious that in this experiment the carrying on of the development of the caterpillars in a magnetic field of considerable intensity had no evil effect upon them.

III. Influence of Electricity and Magnetism on the Development of Trout Ova.

With the object of ascertaining what effect, if any, is produced upon fish ova by allowing them to hatch either in a magnetic field or between the poles of a battery, I arranged three tanks, fed by water from the same tap, but not communicating with one another, as each had its own overflow. At the angles of one of these, and in the line of the current of water, were dipped the poles of two sawdust Daniell batteries. Over the second I suspended the horseshoe magnet used in the silkworm experiment, with the poles downwards, and just above the level of the contained water. It was ascertained by the use of a compass that the entire of the tank was well within the field of the magnet. The third tank was used as a control. In each of these tanks about three hundred ova of the trout were placed. They were of different ages, from those only with danger capable of travelling, to eyed specimens. I obtained them from the Trent Fishery Company at Milton, and was able to place them in my tanks a few hours after they had left that place. The results of the experiment carried out under the above-mentioned conditions may be summed up as follows. In the control tank, one hundred and fifty in all hatched out; in the electric, one hundred and seven; and in the magnetic, thirteen. And the deaths were in a similar ratio amongst the fry, for the thirteen lived but a very short time after hatching, and those in the electric tank had all died at a period when there were still a large number (I omitted to take a note of the exact figure) alive in the control. At first sight it would appear as if this experiment proved that the influence of electricity exercised an evil influence upon the development of these ova, and magnetism one of still greater harmfulness, but I am doubtful whether this should be considered as

the true explanation of what occurred. I asked my friend Professor Poynting, for whose kind assistance in these experiments I am very grateful, to look at the experiment when it had been a sufficient time in operation to enable me to form an idea of the direction in which it was tending. He pointed out to me that the running water underneath the poles of the magnet would set up currents of electricity probably much more powerful than the exceedingly small current generated by the Daniell. If this be true, as doubtless it is, it seems probable that the disturbing factor was electricity in both the tanks, and that the more complete failure to develop in that over which the magnet was suspended was due to the stronger current passing through it.

It would be very rash to attempt to express any definite or confident opinions on the results of the above-detailed experiments. It may, however, be said that my experiments tend to prove, especially when taken in conjunction with those of Lombardini,[1] that electricity produces an arresting effect upon development, whilst it seems to me very doubtful whether a magnetic field has any definite effect upon development or not.

[1] "Forme organiche irregolari negli Uccelli e ne' Batrachidi," Pisa, 1868.

ON THE UNSYMMETRICAL DISTRIBUTION OF THE CRANIAL NERVES OF FISHES. By WALTER E. COLLINGE, F.Z.S., *Demonstrator of Zoology and Comparative Anatomy, Mason College, Birmingham.*

IN some recent investigations upon the relations of the cranial nerves in fishes to the sensory canal system, I have had occasion to dissect a large number of fishes belonging to the same species, and some interesting features have been noted as regards the distribution, branching, and commissural connections of certain cranial nerves, particularly the trigeminal and facial, on the right and left sides of the head of the same fish.

It has not, I believe, been previously pointed out that there is a large amount of variation in these characters between the two sides of the head; in other words, *all the cranial nerves in fishes are not always homotypical.* I emphasise this fact, because I can find no mention of it in any of the accounts of the distribution of the cranial nerves, and also because it will, I think, explain a number of the differences found in the accounts of two authors describing the same species.

How far this condition obtains in other vertebrates I cannot say; but attention having once been directed to the subject, further observations will probably be forthcoming.

Below, I have described some of these variations met with in four different genera.

1. *Clarias magur.*

In a specimen of *Clarias*, the trigeminal and facial nerves of both sides of the head were carefully compared. On the right-hand side a commissural connection existed between the first branch from the ramus buccalis (trigeminal) and the ramus ophthalmicus superficialis. The branch in question innervates a sensory organ of the sub-orbital branch of the main sensory canal of the head, which is situated some little distance posterior to the orbit, the branch of the canal passing through the post-orbital bone. There was no commissure present on the left side.

2. *Amiurus catus.*

The cranial nerves of *Amiurus* have been very carefully described by Ramsay Wright.[1] I have already pointed out a number of differences between this author's account and the condition found in specimens I have dissected, and now wish to note some of the differences found in the same specimen between the right and left sides of the head.

On the left side of the head a distinct commissure was found passing from the ramus mandibularis (trigeminal) on the inferior border of the orbit, to the ramus palatinus (facial); there were also two smaller commissures beneath this, which passed from the commencement of the buccalis to the ramus mandibularis. None of those were present on the right side.

In another specimen on the right side of the head there was a commissural plexus, between the ramus buccalis and ramus maxillaris, a feature common to very many of the Physostomi; in this case, however, it was entirely absent on the left side. The ramus palatinus, as pointed out by Professor Ramsay Wright,[2] passes through the anterior portion of the *adductor arcus palatini*, forming two branches. These two branches, however, are not constant, as sometimes it terminates in a number of fine branches which supply the mucous membrane of the lips, and also spread over the anterior region of the roof of the mouth.

3. *Esox lucius.*

In nearly all the specimens of *Esox* dissected, a commissure was observed passing from the commencement of the ramus buccalis (trigeminal), and anteriorly becoming connected with ramus maxillaris. In another specimen on the right side of the head, a branch passed off from this commissure forwards, and in a dorsal direction, joining with the ramus buccalis. In two specimens the commissure was absent on the left side of the head, and in another it formed a small plexus on the right side only.

A branch of the facial nerve which passes from the ramus

[1] *Proc. Canadian Inst.*, 1884, vol. ii., N.S., pp. 352–86, pls. 1 part iv.–vi.

[2] *Op. cit.*

hyo-mandibularis at the head of the pre-operculum and forwards in a ventral direction, in two or three cases was found to vary greatly in its length and number of divisions, and these often differed on the two sides of the head, *e.g.* on the left side of one specimen it extended forwards in front of the orbit, whereas on the right side it terminated 15 mm. posterior to the orbit.

4. *Gadus morrhua.*

The chief variations noted in some eight or nine specimens of the cod, were the presence or absence on one side of the head of commissural connections between the ramus buccalis (trigeminal) and ramus maxillaris, in one case ramus mandibularis. This latter was present on the left side only, and formed a plexus on the inferior and posterior border of the orbit.

It is just possible that these differences in the trigeminal and facial nerves are peculiar to fishes, and due to the number and distribution of the sensory organs of the head, which are not always homotypical.

From the foregoing observations it would seem that certain cranial nerves—particularly the trigeminal and facial—are liable to a marked variation on one side of the head from the condition which obtains on the opposite side.

The commissural connections are not always present, being absent in one specimen and present in another of the same species, and present on one side of the head and absent on the opposite. Commissural plexi between two or more branches may also be present on the one side and absent on the opposite.

The branching is liable to a wide variation as regards the number of the finer branches.

For a right appreciation of the distribution and branching of the trigeminal and facial nerves in fishes, both sides of the head should be examined, and in a number of specimens.

THE STRUCTURE OF THE INFERIOR MAXILLA WITH SPECIAL REFERENCE TO THE POSITION OF THE INFERIOR DENTAL CANAL. By EDWARD FAWCETT, M.B. Edin., *Professor of Anatomy, University College, Bristol.*

So far as I know, no complete account exists of the Structure of the Inferior Maxilla, nor is anything beyond a somewhat broad reference made to the position of the Inferior Dental Canal in that bone. The object of this paper is to make up this deficiency, and the statements made in it are based upon observations made on sections of a great number of bones. There are so many varieties of construction of the lower jaw that it is difficult to fix on any one as being typical. Many that I examined in the macerated condition were practically devoid of cancellous tissue in the interior, and the inferior dental canal had disappeared, the bone being a mere shell; others, again, were practically solid, so that the terms "pneumatic" and "diploëtic" might almost be applied, as in similar conditions of the mastoid process: fortunately, however, a good many jaws show both cancellous and compact tissue, and with such I propose to deal in this paper, choosing to regard them as typical. My conclusions are based on serial *coronal* sections of the jaw made from the symphysis menti to the neck, and *horizontal* sections through the neck and condyle.

Method of procedure.—The jaw was first divided mesially, and one-half was laid flat on a table against a block of wood with a transverse slot in it, wide enough to admit a fine tenon-saw, much after the fashion of a mitre block used in making picture-frames. With this aid I was enabled to cut perfectly straight sections. As far as possible the sections were made equal in thickness, though the thickness depended to a certain extent on the size of the tooth alveoli. The saw was carried through the middle of the alveoli and through the septum between adjacent alveoli. The sections through the coronoid process and ramus were as far as possible equal in thickness to those of the body.

General Appearances.—It will be found convenient to study the general appearances of sections taken at four different points, and I shall in the first place describe a section through the *body*

of the jaw,—it matters little at what point, so long as it is behind the mental foramen. If the section be taken through an alveolus (figs. 7 to 13) it will be seen to consist of a shell of compact bony tissue, somewhat U-shaped, with the vertical limbs of the U connected by a thin bridge of compact tissue, depressed in the middle to form an alveolus. The lateral and inferior walls are much thicker than the superior, which contains the alveolus.

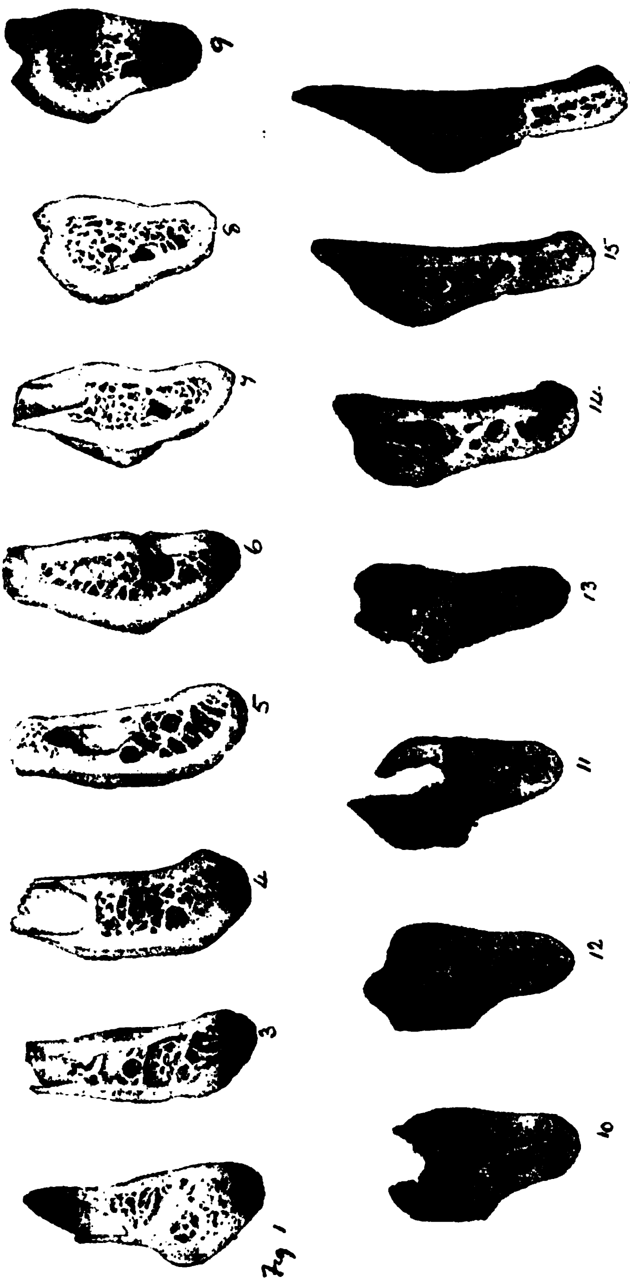
This shell of compact bone is marked, as is well known, by various ridges or lines, grooves, and fossæ, by structures attached to it or in close contact with it. Most of these have little bearing on the question under consideration; and with the exception of the internal oblique line, and the groove for the mylo-hyoid nerve and vessels, I shall ignore them.

The outer wall of compact tissue, as seen in our section, is for all practical purposes flat or slightly concave, whereas the inner wall differs markedly from it in being concavo-convex, the convexity in the upper half being caused by the internal oblique line or mylo-hyoid ridge, the concavity below being partly the result of that projection and partly due to the submaxillary gland. In this hollow the groove for the mylo-hyoid vessels and nerve can be traced in well-marked bones as far as a point opposite the second molar tooth. This groove is of considerable importance, inasmuch as it indicates with tolerable accuracy the downward course taken by the posterior half of the inferior dental canal. The shell of compact bone encloses a network of cancellous tissue and the inferior dental canal. The cancellous tissue consists of trabeculæ which, springing from the shell of compact tissue, interlace with one another in an irregular fashion, to form a network whose meshes are for the most part irregular, and generally very small. Embedded in this cancellous tissue, at about the junction of the upper two-thirds with the lower third of the bone, and for the greatest part of its extent, lying against the inner wall, is the inferior dental canal, which may be distinguished from the surrounding meshes by its greater calibre and regularity of walls, which are formed by a thin layer of compact tissue. We may also see the socket for a tooth reaching a considerable way down, and contracting to a point as it terminates, which it does a very little way above the inferior dental canal. From the wall of the socket trabeculæ project on all sides—in fact, the wall of the socket

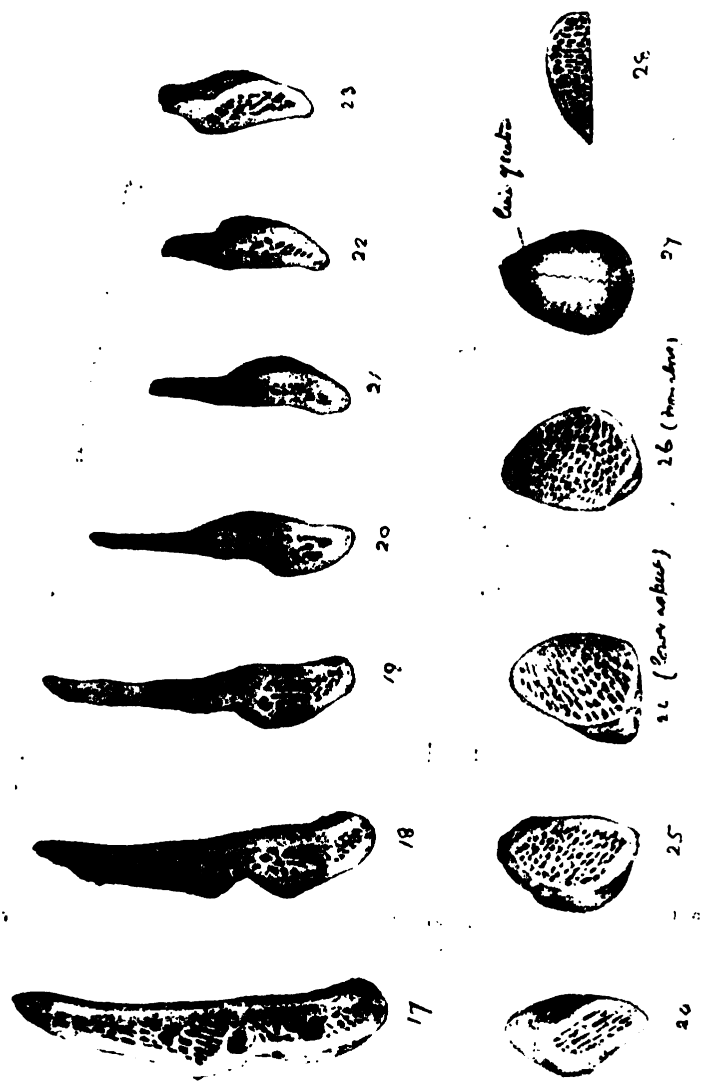
may be regarded as consisting of the fused ends of numerous trabeculæ. Each socket is perforated at its apex or point for the vessels and nerve to the tooth contained, and in its wall near the base innumerable small foramina can be seen, connected in the recent condition with the periodontal membrane.

Such are the general appearances presented by a section through the body of the jaw.

Sections through special regions of the jaw.—Now let us examine a section through the *coronoid process and ramus* (figs. 18, 19, 20). The appearances of such a section vary with the site at which it is taken. If *anterior* to a line connecting the tip of the coronoid process with the angle of the jaw, the section will be modified by the inferior dental canal and the temporal muscle; if *posterior* to that line the inferior dental canal will be absent, though the inner wall will show the groove leading to that canal, and we may or may not cut through the area occupied by the tendon of the temporal muscle; if the section be behind the temporal area the coronoid process is practically solid, differing in this respect from the part occupied by the temporal muscle. A section made through the line mentioned above will cut through the base of the lingula, and either just catch the beginning of the inferior dental canal or run through the groove leading to it. In most of my own sections the groove is cut through immediately behind the canal, and on this understanding I shall describe the appearances presented by such a section which is practically like that numbered 18 in the plate. It shows a shell of compact bone somewhat thinner than that of the body, and different in shape also, of course. There is no upper (alveolar) thin wall of compact tissue, the outer and inner walls running together to a point above; no tooth socket is seen; in other respects the compact tissue of this segment is like that taken from the body of the jaw. The cancellous tissue, here above the level of the inferior dental canal, differs markedly in arrangement from that of the corresponding area in the body of the jaw. The trabeculæ no longer form an irregular network enclosing somewhat circular meshes, but they are arranged for the most part in parallel rows which, springing from the inner wall of the coronoid process and the roof of the inferior dental groove, pass upwards nearly parallel with the inner wall, though deviating a little from



Sections 1–5 are anterior to mental foramen. Section 6 is through mental canal. Sections 7–13 are posterior to mental foramen and anterior to ramus and coronoid process. Sections 14–23 are through ramus and coronoid process. Sections 24–26 are through neck. Sections 27, 28 are through condyle.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it on their way, so that they end on the outer wall, forming with it a very acute angle. These trabeculæ are laminar in form, with their surfaces directed laterally, and they are connected together at short intervals by short and much weaker thread-like trabeculæ placed at right angles to them, so that the long interlaminar spaces are broken up into rectangular, oblong, or elliptical short spaces. The cancellous tissue occupying the area below the dental groove resembles that of the body of the jaw in being composed of an irregular network of trabeculæ, though it also, near the lower wall, may show an attempt at parallelism of trabeculæ with much the same direction as those of the area above the groove.

This parallel arrangement of fibres is certainly due to the traction exerted by the temporal and masseter muscles.

It is well known to all anatomists that the direction of the trabeculæ of cancellous tissue is largely dependent on two forces, viz., pressure (and the opposite of pressure—traction) and tension; and here we have an excellent example of trabeculæ arranged by traction of two muscles, viz., the temporal and the masseter. The trabeculæ are parallel to neither tendon, but to the resultant of contraction of the two.

I have said that slight parallelism of trabeculæ may be seen in the lower area: this is produced by traction of the internal pterygoid and masseter muscles.

There can be no doubt about traction being the cause here; for if we make sections anterior to the attachment of the temporal muscle, the cancellous tissue in the upper area becomes irregular, and shows not the slightest attempt at parallelism of trabeculæ. Further examples will be met with as we pass on.

Let us now examine the structure of the *neck* of the jaw. This is best done by making a horizontal section through the neck just below the condyle, cutting through the fossa for insertion of the external pterygoid muscle. Such a section is somewhat triangular, with the apex inwards. The shell of compact bone is much thinner than in the other sections, and the enclosed cancellous tissue in the form of a very small-meshed network, the main trabeculæ of which run forwards and somewhat outwards, and are more or less parallel to one another. In many sections these trabeculæ run quite sagittally (figs. 24, 25, 26).

In the *condyle* (figs. 27, 28) the compact tissue is still thinner where it forms the articular surface, and the cancellous tissue, when looked at in horizontal section, forms a close, small-meshed network, but when seen in coronal section, shows the main trabeculæ running vertically upwards and parallel with one another: here evidently pressure has to be resisted more than traction.

The Inferior Dental Canal.—We may now turn our attention to the inferior dental canal and trace it from beginning to end. This canal commences in the ramus of the jaw, midway between its anterior and posterior borders, and at the point of junction of the lower one-third with the upper two-thirds of a line drawn between the tip of the coronoid process and the angle of the jaw, and on a level with the upper surfaces of the molar teeth (*Quain*), by a funnel-shaped aperture; but for some little distance behind the real commencement of the canal a groove exists on the inner wall of the ramus which, caused by the inferior dental nerve and vessels, runs downwards and forwards into the canal; and the entrance to the canal is often concealed by that free end of the splenial called the lingula, to which the so-called internal lateral ligament of the jaw is attached.

A section made through the beginning of the canal shows it to be pyriform, with the large end downwards and slightly outwards, the small end upwards and inwards, and in its long axis being about 7 mm., its width being 3 mm. Three millimetres in front of this point the long diameter has fallen to 3½ mm., the transverse to 2½ mm., and the canal here is seen to be half embedded in the inner wall of the jaw, and more so at its upper end than at its lower, on account of the obliquity of its long axis. The outer wall of the canal consists of a thin shell of compact tissue connected by trabeculæ with the outer wall of the jaw. The direction of the canal at this point is forwards, downwards, and slightly outwards (fig. 18).

In the segment of the coronoid process and ramus (fig. 17), immediately anterior to the last, and 4 mm. in thickness, the canal travels outwards, so that its outer wall blends with the outer wall of the jaw, and whilst its inner wall is blended with the inner wall of the jaw; the latter is not grooved by the canal as it was in the previous segment, and as it is indeed at the back

of the present segment. The canal still is directed forwards, downwards—markedly—and slightly outwards, and it lies at about the junction of the upper two-thirds with the lower third of the segment.

The next segment, taken immediately anterior to the last, and, like it, of the coronoid process and ramus, and 4 mm. thick (fig. 16), shows the canal still tending outwards, so that it has at its anterior end slightly grooved the outer wall of the jaw, but its inner wall is still blended with the inner wall of the jaw. The lumen is somewhat bluntly pyriform in shape, with the small end directed upwards and inwards, and the general direction of the canal is downwards, forwards, and outwards.

In the next segment of the coronoid process and ramus the canal still grooves the outer wall of the jaw and reaches the inner wall, is now oval in section—it may be divided almost into two here by a septum of bone; its long axis is oblique, the upper end being directed inwards, the lower outwards. The upper and lower walls are very thick. This segment is 3 mm. in thickness.

The next segment, also 3 mm. in thickness, includes the root of the coronoid process just behind the last molar tooth (fig. 14). The lumen of the canal is now almost circular. The canal itself still grooves the outer wall; is directed downwards, forwards, and a little outwards. Both its upper and lower walls are thick.

The next segment (fig. 13), 4 mm. thick, included the posterior part of the obliterated socket of the last molar tooth. In this the lumen of the canal is oval, with the long diameter now vertical, and the canal, though lying nearer the outer wall of the jaw, no longer grooves it, and is directed at its anterior end forwards and a little downwards, with no inclination outwards. The upper and lower walls are somewhat thinner than in previous segments.

The next segment, 3 mm. in thickness, includes the middle of the obliterated socket of the last molar tooth (fig. 12).

Here the lumen of the anterior end of the canal is almost circular and lies *midway* between the outer and inner walls of the jaw, and the canal is now looking forwards, downwards, and slightly inwards at its anterior end. Its lower wall is now within 7 mm. of the lower border of the jaw.

The next segment (fig. 11) includes the posterior half or so of the socket for the second molar tooth. The anterior lumen of the canal, still nearly circular in form, is seen against the *inner* wall of the jaw; the outer wall of the canal is now quite separate from the outer wall of the jaw, though connected with it by trabeculæ, and the canal is now directed forwards, with very slight inclinations downwards and inwards. Its lower wall is now 6 mm. from the lower border of the jaw.

The next segment includes the anterior part of the socket for the second molar, and is 4 mm. thick (fig. 10). The canal is again oval, with long diameter vertical; it slightly grooves the inner wall of the jaw; its outer wall is very thin, and separated by an interval of 2 mm. from the outer wall of the jaw. Its direction is forward, slightly inwards, and very slightly downwards. Its lower wall is 5 mm. from the lower border of the jaw.

The next segment includes the posterior half of the obliterated socket of the first molar tooth, and is 4 mm. thick (fig. 9). The canal, vertically oval, grooves the inner wall; its very thin outer wall is 2 mm. from the outer wall of the jaw, its direction is *absolutely forwards*. The lower wall is 7 mm. from the lower wall of the jaw.

The next segment includes the middle of the obliterated socket of the first molar tooth. The canal, still vertically oval, has a very thin outer wall, separated by an interval of nearly 3 mm. from the outer wall of the jaw. Its direction is now at its anterior end forwards and very slightly *outwards*. The distance of its lower wall from that of the jaw is 7 mm.

The next segment (fig. 7) includes the anterior half of the obliterated socket of the first molar. It shows the canal, vertically oval, now separated at its anterior end, very slightly separated from the inner wall of the jaw by cancellous tissue, and 2 mm. from the outer wall of the jaw. It is directed forwards, outwards, and very slightly *upwards*. Its lower wall is 8 mm. from the lower wall of the jaw.

The next segment (fig. 6) includes the posterior half of the socket for the second bicuspid tooth. The canal, once more circular in lumen, has very thin walls, which are free, the inner 1 mm. from the inner wall of the jaw, the outer 1½ mm. from the outer wall of the jaw. Its direction is forwards,

slightly upwards, and markedly outwards. Its lower wall nearly 9 mm. from the lower border of the jaw.

The next segment, 4 mm. in thickness (fig. 5), includes the anterior half of the socket for the second bicuspid, and the posterior two-thirds of the canal for the mental nerve and vessels. The dental canal may be said to terminate here, by bifurcating into "mental" and "incisive" canals; and at the point of bifurcation, which takes place some little distance behind the point where the mental canal pierces the outer wall of the jaw, the canal lies against the *outer* wall of the jaw, is circular in lumen, and is 2 mm. from the inner wall of the jaw.

The "mental canal" runs at first forwards, outwards, and upwards, say in its first third upwards and outwards, in its middle third and backwards upwards, and outwards in its last third, ending at the mental foramen, in the adult jaw vertically below the ridge separating the second from the first bicuspid tooth, though this depends on race, and midway between the alveolar and lower borders of the jaw, this depending on age and the presence of teeth. The whole canal is about 5 mm. in length.

This segment shows very beautifully the exterior of the socket of the second bicuspid tooth and the trabeculæ in connection with it, and on looking into the cavity of the socket a considerable foramen can be seen at its apex which leads to the dental canal.

In the next segment (fig. 4), which includes a little of the anterior part of the mental canal and a good part of the socket for the first bicuspid, we have to deal with the "incisive" canal. This in the posterior part of the segment lies against the outer wall of the jaw, but after a course of 4 mm. is separated from that wall by a small amount, say 1 mm. in thickness, of cancellous tissue. Its direction is therefore forwards and inwards. The lumen is circular, much less in size than that of the dental canal, and the walls are very thin.

The next segment (fig. 3) includes the posterior part of the socket for the canine tooth. Here the "incisive" canal, 1½ mm. in calibre, lies almost midway between the outer and inner walls of the jaw, and has very thin walls. The anterior lumen is circular, and the canal is directed forwards, slightly inwards, and upwards.

The next segment (fig. 2) includes the apex of the socket of the canine tooth, as well as a little of the upper posterior part

of that of the lateral incisor. This segment is 4 mm. thick. The incisive canal in the anterior half of this segment bifurcates, or, in other words, is divided into two parts, by a vertical septum: both resulting canals are very narrow, and lie midway between the anterior (outer) and posterior (inner) walls.

The next segment includes the greater part of the socket of the lateral incisor and the lower and posterior half of that of the medial. Here no trace of an incisive canal can be distinguished from the lumina of the cancellous tissue. The cancellous tissue here is very loosely arranged, though the main trabeculæ run downwards and backwards from the anterior wall to the posterior wall of the jaw; this direction being evidently due to traction exerted by the hyoid muscles and the anterior belly of the digastric.

The last segment (fig. 1) includes the greater part of the socket for the medial incisor and the left genial tubercles. It is interesting because it shows a strong bar of bone passing horizontally forwards from the upper genial tubercle to very near the anterior wall, which it ultimately reaches, having, however, previously broken up into a bunch of thick trabeculæ.

Let us now sum up the various facts yielded in the course of our examination of the position and course of the inferior dental canal and of its continuation, the "incisive" canal. We have seen that for the first 6 mm. of its course in the ramus of the jaw it lay in the inner wall of the jaw, and was separated from the outer by a small amount of cancellous tissue; in the next 8 mm. of its course, that it was midway between the two walls; in the next 8 mm. it was nearer the outer wall than the inner—in fact, grooved the outer wall; in the next 4 mm., that is, when under the first molar tooth, it lay midway between the two walls; that beyond that, to the level of the second bicuspid tooth, it lay against the inner wall of the jaw; and that from that point it inclined rapidly outwards, and in a course of some 4 mm. it gained the outer wall to and by bifurcating into mental and incisive canals; that the incisive canal, after a course of something like 6 mm., reached a point midway between the two walls of the jaw, and was finally lost sight of 4 mm. anterior to this, just below the apex of the socket of the canine tooth, or below the outer edge of the lateral incisor tooth. We have seen that the canal descended till it lay under the socket of the first molar tooth at its

posterior part, and that when under the anterior part of the socket of the first molar, or the septum between that and the socket of the second bicuspid, it began to rise, and continued to do so till it ended by bifurcating under the septum, between the second and first bicuspids. From what we have seen, then, it is evident that the position and course of the inferior dental canal are not quite so simple as the text-books would have us suppose. The figures I have quoted cannot, of course, be accepted as absolute, as probably no two jaws agree in dimensions, but they serve a useful purpose here, in delimiting the canal and its surroundings, and for that purpose alone have I submitted them. They are simply representative of the particular specimen I have described. The general course of the canal, its situation at various points of the bone, as stated here, may be taken as representative of the normal course and situation of the canal, as they agree with what I have seen in observations made on a considerable number of bones, and extended over a long period.

It may be thought that these results concerning the inferior dental canal might have been more easily obtained, and perhaps more accurately, by making longitudinal horizontal sections of the jaw, and by removing the outer wall; but though these methods are useful, they, I think, can only be considered as adjuncts to the method I have adopted, and may be used to verify results so obtained; and as the two latter methods fully confirm the statements I have made under the first method, there is no need for me to enter into further description of them, or the results obtained by their use, though I might perhaps say that in many specimens which have been cut horizontally along the internal oblique line, well-marked trabeculæ can be seen starting out from that line to act as tie-beams between it and the outer wall of the jaw: evidently these result from traction exerted by the mylo-hyoid muscle.

Lastly, let me incidentally mention the relationship of the occupants of the inferior dental canal, as though, perhaps, it is well known, yet in no text-book that I am familiar with is it alluded to. The chief occupants are, of course, the inferior dental nerve and artery. At the entrance into the canal, the artery lies behind the nerve; beyond that point, and so long as the canal descends, the artery usually lies below and behind the nerve; subsequently the artery in nearly all cases lies on the outer side of the nerve. These remarks, of course, relate to the unmacerated jaw.

THE EXTENSIBILITY OF MUSCLE. By T. GREGOR. BRODIE, M.D. (Lond.), *Demonstrator of Physiology, King's College, London.* (PLATES VI., VII.)

(From the Physiological Laboratory, King's College, London.)

THE following work upon the extensibility of muscle originated some time ago from a consideration of the inaccuracies, mainly instrumental, which are to be found in all the ordinary methods commonly employed. These altogether preclude any correct mathematical deductions from the curves obtained. Hence it seemed desirable to commence a re-examination of the whole question, and to attempt to obtain a curve that should with mathematical accuracy represent the true elongations of a tissue under a succession of weights. I soon found that the instrumental difficulties to be overcome were considerable, and a large amount of time has been spent in the manufacture and testing of several forms of apparatus.

The conditions which I set myself to fulfil were the following:—

1. The loading of the muscle must be quite regular, equal increments being added in equal times; and the unloading must be at the same rate, and with the same regularity.

2. The elongation of the muscle at any instant must be accurately multiplied and recorded.

3. The abscissæ of the curve must represent the weighting, while the ordinates (measured at right angles to the abscissa line) must represent the elongations.

Varying forms of apparatus have been employed by previous experimenters. Weber,[1] for instance, took by a cathetometer successive measurements of the lengths of a piece of tissue to which weights were successively added. This only gives a series of measurements, not a continuous curve, and for that reason I discarded it. Moreover, though it seems simple, and capable of the greatest accuracy, yet in actual practice many difficulties

[1] E. Weber, Wagner's *Handwörterbuch*, iii. 2, 1846.

are encountered, the chief one being that the tissue is continually stretching for some time after the weight has been attached. It is, too, a most tiring process, and forms an experiment which occupies a considerable time.

Marey[1] obtained his curves by running a stream of mercury into a receiver supported by the muscle. The unloading was effected by turning a tap at the bottom of the receiver, and thus allowing the mercury to run away. The movements of the lower end of the muscle were recorded and multiplied by a long lever carrying a writing point at its extremity. Roy[2] loaded the tissue (artery, &c.) by running a weight along a lever supported near its fulcrum by the tissue. The elongations were multiplied and recorded by this lever, which carried a writing point at its free extremity. This method will not give perfect results, for two reasons: first, the unloading at the same rate as the loading is extremely difficult, if not impossible, to attain; and secondly, the elongations are recorded by a simple lever. This does not accurately multiply the elongations when the angular movement exceeds a small limit, and further, when it has passed this limit it is still less accurate, because the writing point moves in an arc of a circle, and not in a straight line perpendicular to the direction of movement of the recording surface.

In my earlier experiments I employed Marey's method, using, at different times, water, mercury, and sand. I soon found, however, that it was extremely difficult to get a constant stream during loading, and that it was quite impossible to get a uniform stream during unloading. The reason of this latter result is that, as the level of the mercury in the receiver falls, the rate of outflow is considerably diminished. Moreover, Marey used a long lever to multiply and record the elongations, and, as above mentioned, this cannot give accurate results when employed beyond a very limited range.

After several trials in other directions, I at last devised an apparatus, of which fig. 1 is a diagram. The muscle or other tissue to be experimented upon—represented by R in the diagram—is held in a strong clamp supported by four vertical metal rods. In this way the upper end is held perfectly rigid.

[1] Marey, *Fonctions de la vie*, p. 299. Germer Baillière, 1868.

[2] Roy, *Journal of Physiology*, iii. p. 125, 1880, and ix. p. 227, 1888.

By a short thread 4 it supports one end of a long metal lever P N which moves about a fulcrum P. Suspended from this lever at a point O is a stout steel spiral spring Y. A stout cord 1, 1 passes over the pulleys A, B, and C, and is kept taut by weights L, J at either end. This cord is moved at a uniform rate in the direction A B by the pulley A, which is driven by powerful clockwork. A carrier M, running along two fixed wires parallel to this cord, can be clamped to it in any position by means of a screw. Attached to the carrier is another cord 2, 2, which passes between two very small pulleys D, D′, and then round the large pulley F, being kept tense by a weight K. As the string 1, 1 moves forward, the carrier M is brought nearer to D and the weight K is consequently lowered. This rotates the pulley F in the direction of the hands of a watch. The two pulleys F and G are fixed upon the same axis. Consequently G is rotated in the same direction as F, and winds up some of the string 3′, the upper end of which is fixed to the spiral Y. In this way the spiral Y is gradually extended, and as the clockwork drives the string 1, 1 at a uniform rate, the extension of Y is brought about at a uniform rate. The two pulleys D and D′ are only slightly grooved, and are firmly fixed in such a position that the bottom of the carrier M just grazes them as it travels past them. As soon as the carrier M passes the centre of the pulleys D D′ the string 2, 2 is drawn up and the weight K ascends. There is therefore a sudden reversal in the direction of movement of the string 2, 2, and the pulleys F, G are therefore rotated in the opposite direction, and the string 3′ is unwound, the spiral Y being thus allowed to shorten. As the movement of the string 1, 1 is uniform the shortening of the spiral is uniform, and at the same rate as that at which it was extended. Now, if the upper end of Y be fixed, it follows that the pull upon that point of suspension will first be increased and then decreased. Further, as the extension and retraction are effected at a uniform rate, and as the amount of stretching of a spiral is, within certain limits, directly proportional to the weight stretching it, it follows that the pull upon the point supporting the spring is first uniformly increased and then uniformly decreased. In the experiment, however, the upper end of the spring is not rigidly fixed, but is attached to O,

which moves downwards as the muscle is elongated. By putting O sufficiently near P we may, however, so diminish this descent that for all practical purposes it may be neglected. In my experiments the distance O P has been $\frac{1}{12}$th of the distance N P, so that if, for example, the muscle is stretched $\frac{1}{4}$ of an inch, O will only descend $\frac{1}{48}$ in.; and as Y is stretched as much as 6 or 8 inches, the error in weighting will only amount to $\frac{1}{288}$th to $\frac{1}{384}$th of the total load. This we may certainly neglect, as falling well within the margin of experimental error. In this manner, then, the downward pull upon O is first uniformly increased and then uniformly decreased, the rate of increase and decrease being the same. This downward pull at any instant is counteracted by the upward pull of the muscle R acting at N, and the upward resistance at the fulcrum P. As O N is eleven times O P the muscle will support $\frac{1}{12}$th of the pull at O and the fulcrum the remaining $\frac{11}{12}$ths. As the pull at O is first uniformly increased and then uniformly decreased, the downward pull at N is also first uniformly increased, and then uniformly decreased, but at each instant with a pull only $\frac{1}{12}$th that at O. Moreover, the rates of loading and unloading are uniform, and depend upon two factors: first, upon the velocity of the string 1, 1; and secondly, upon the strength of the spiral Y. In my experiments I have made use of both of these factors. Where a great increase in rate is required, I use a spring of greater strength. Where only a small increase is desired, it becomes more convenient to alter the rate of the clockwork. Variations in the amount of the maximum stress put upon the muscle can be brought about in three ways. First, by altering the position of O. Secondly, by using springs of different strengths, but stretching them though equal lengths. Thirdly, by altering the distance of the starting-point of the carrier M from the small hole between the pulleys D, D′. The first of these methods I never employ, for, as above shown, it is necessary that O should be as near to the fulcrum P as is convenient. Where it was necessary to make considerable alterations in the loading I have used springs of different strengths. When the alteration required was small, the method employed was to alter the position of the carrier M on the cord 1, 1. The distance M D in each experiment is read off upon a scale fixed

to the table. Having fixed the position of the carrier M, the pulleys F, G are rotated until the thread 3′ is just tightened up.

The springs have all been carefully calibrated in the following way. It was first determined by measurements with a cathetometer how far the spring Y was stretched by a movement of the carrier M through a distance of 5 cm. This elongation is of course the same for each distance of 5 cm. travelled by M, no matter where the starting-point of M be taken. Let us call this measurement *d*. It does not, of course, vary with the spiral used. The spiral was removed, suspended from a rigid point, and the height of its lowest point read off on a cathetometer. A small vessel was now suspended from its lower end, and mercury added until this end had descended through a distance *d*, when the receiver was removed and weighed. It was then replaced and more mercury run in, until it had descended through a second distance *d*, when it was again removed and weighed. This process was repeated seven times. The weighings were all taken to decigrammes, and as the load on the muscle is only $\frac{1}{12}$th of that on the upper attachment of the spiral, this load is calculated to centigrammes. This I considered sufficiently accurate for the purpose. Below I append the figures obtained during the calibration of one of the springs. It gave very close results, and was one of the best springs I have measured, and the one which I have most frequently employed. Several were very irregular and could not be used with any accuracy, so were replaced by others.

The distance *d* was found to be 19·4 mm.

Spiral stretched.	Stretching weight.
19·4 mm.	58·25 grms.
38·8 „	116·3 „
58·2 „	174·5 „
77·6 „	232·8 „
97·0 „	290·75 „
116·4 „	348·8 „
135·8 „	406·85 „

This gives an average of 58·12 grms. required to stretch the spring through 19·4 mm., and is very accurate within the limits given above.

The second condition mentioned on *p* 367 has next to be considered. The ordinary method of multiplying any movement by means of a lever with a writing point attached introduces a considerable error, for as soon as the angular movement exceeds a certain very small amount the multiplication is no longer mathematically accurate. There is a still worse error, for the writing point moves in an arc of a circle whose centre is the fulcrum and is not restricted to movement in a straight line at right angles to the direction of movement of the recording surface.

I have avoided these errors by making use of the arrangement of levers indicated in Pl. VI. fig. 1 by the lines ST, TV, and VW. In that diagram, however, it appears as though there were some attachment of TV to $\beta\beta$ at the point U. This would interfere with the free movement of the wire $\beta\beta$, and has been overcome by the arrangement depicted in Pl. VI. fig. 2, where it is seen that T V really consists of four segments firmly united together, and pivoted at the two points P, Q, so allowing the wire $\beta\beta$ to pass between them. The dotted line TV in figure 2 corresponds to the line TV in fig. 1, and it is this line which it is necessary to take into account in the mathematical consideration of the action of the levers.

The end of the lever PN in fig. 1 has attached to it another thread 5 which runs round the pulley Q and is attached to one end of a fine horizontal steel rod $\beta\beta$. To the other end of this rod is attached another thread 5′ passing over a second pulley Q′ and kept tense by a weight X. The weight X just counterbalances the weight of the lever PN and the spiral Y. In this way any movement downwards of N is communicated exactly to the metal rod $\beta\beta$. Attached to $\beta\beta$ at S is one end of the system of three levers S T, T V, V W. These move about a fulcrum at U and are so arranged that ST = TU and UV = VW. They are jointed at S, T, and V. The joint at S is so made that it can be slid along $\beta\beta$ and clamped in any necessary position. The end W of the lever VW rests upon a horizontal writing surface ZZ whose direction of movement is perpendicular to the plane in which the lever moves, *i.e.* it moves perpendicularly to the plane of the paper. In fig. 3 are drawn two positions of these levers, viz., ABCDE and A′B′CD′E′. Now in the two triangles ABC, CDE, the angles ACB and DCE are

equal, and as $AB = BC$ the angle CAB = the angle ACB, and similarly the angle DCE = the angle DEC, and they are therefore all equal to one another. Consequently the remaining angle at D is equal to the remaining angle at B, and the two triangles are similar to one another. Hence $\frac{AC}{CB} = \frac{EC}{CD}$.

In the apparatus CD is so chosen that it is five times CB. Hence $CE = 5CA$. Similarly for the new position $A'B'CD'E'$. $CE' = 5CA'$ and therefore $EE' = 5AA'$. But AA' represents the movement of the muscle, provided the angular movement of PN about P be small. Hence EE' represents five times that movement. This is the movement recorded, and it is registered by a movement at right angles to the direction of movement of the recording surface. The writing point W is of glass and writes upon a blackened paper surface. The writing point moves between two fine wires stretched just above the recording surface and at right angles to its direction of movement. The levers ST and TU are of steel, while the long levers UV (which is double) and VW are very light straws. The joint at V is made of aluminum and is very light. The weight X is so adjusted that it will exactly support the end of the lever N before the muscle is placed in position—the spring hanging from that lever at O.

In a number of the experiments there was at the start no pull on the muscle, in other cases I have started by placing the muscle under a tension of three, five, or ten grammes. The method I have employed to effect this is to attach a second string to the lower end of the spring Y, this second string being fixed below to the floor. On shortening this string the spring is lengthened; and as the amount of tension placed on the muscle depends on the amount of stretching of the spring, all that is necessary is to determine how far the spring must be stretched to produce a pull at N of three, five, and ten grammes respectively, and regulating the length of the string accordingly.

In the tracings obtained, the ordinate of any point represents five times the actual extension and the abscissa the amount of load at that instant. We have seen that the ordinates are a perfectly accurate multiple of the elongations of the muscle: it is most essential then, in order to get a true curve, that the abscissæ should accurately represent the amount

of load. First, it is necessary, in order to produce this result, that the spiral spring should be as nearly perfect as possible. Those I have selected and used from among many are, within the limits at which they are used, very nearly so. Consequently the load at any given instant is directly proportional to the distance the carrier M on the string 1, 1 has moved. Hence if the recording surface is moved at a rate directly proportional at each instant to that of the string 1, 1 the abscissa at any instant will be directly proportional to the load at that instant. This uniformity of movement between the string 1, 1 and the recording surface is attained by driving the recording surface by the same clockwork which moves the pulley A. Then any irregularity in the movement of the string 1, 1 is accompanied by an exactly proportional alteration in the movement of the recording surface. Any alterations in the rate are detected by the use of a time marker writing on the same surface. There are slight changes, but these are so extremely small that they may be neglected.

To test the accuracy of the apparatus, I first fixed a spiral spring in the position of the muscle R, and examined the tracing so obtained. On theoretical grounds the tracing should consist of two straight lines, as in fig. 4, where A B represents the line recorded during the loading of the muscle, and B C during the unloading. These lines should be equally inclined to the zero abscissa line A C, and there should be no blunting of the angle at B. Figs. 5^A and 5^B are copies of tracings actually obtained, and there we notice that the two lines are as nearly as possible straight, but there is a blunting of each apex. This blunting is the result of friction present in the recording levers, and mainly where the horizontal wire $\beta\beta$ passes through two guides, which are not indicated in the diagram.

Its influence upon the curve is illustrated by fig. 6. In this figure A H C is drawn to represent the tracing that should theoretically be obtained; while A B K F E L is the tracing supposed to be recorded. It is immaterial whether the spring start from rest, or with an initial load. Let us suppose the friction to be of such an amount that it would require a force of x grammes to set the levers in motion. Now, this force will not vary during each experiment, because the pressure on each joint of the recording system remains the same throughout the

whole experiment. Let us consider the conditions of movement of the point N in fig. 1 at the commencement of the experiment. This point is supported by two strings: one attached to the lower end of the spring which is being experimented upon; the other, after passing over a pulley on agate bearings, is attached to the end β of the system of recording levers. Both these strings are taut. Now, until the pressure pulling N down reaches x grammes it is obvious that N cannot descend, for nothing less than a pull of x grammes can set the system of levers in motion. A B, therefore, represents x grammes. As from this time onwards the recording levers are always in motion, it follows that the actual pull upon the lower end of the spiral experimented upon (R) is equal to $P-x$ grammes, when P is the downward pull upon N at that instant. Consequently the actual tracing obtained consists of the lines A B and B K (fig. 6), where B K is parallel to the theoretical line A H. Also the vertical distance P Q between them at any point P divided by the amplification of the system of levers is equal to the elongation of the spiral experimented upon when loaded by a weight of x grammes. Thus P Q = K H = five times the elongation of the spiral R when loaded with x grammes. We have now reached the apex of the curve, and here, though the value of x remains the same, its sign changes, for the movement will now be in the opposite direction. Let us suppose the downward pull upon N at its greatest is P_1. Then the greatest pull upon the spring R is P_1-x. Suppose, too, that the pull at N when R begins to retract is P_2. Then the upward pull of R must be so great that not only will it be able to overcome the pull of N downwards, viz., P_2, but can also exert an extra force of x grammes, so as to move the recording levers. Hence its force at that time is P_2+x. The point to determine is, when will the spring R begin to move upwards? Now, the maximum upward force R can exert is P_1-x, so that R will just begin to move upwards as soon as

$$P_2+x = P_1-x$$

$$\text{or,} \qquad P_2 = P_1-2x.$$

Until that time is reached the writing point will remain stationary.

Interpreting this on our diagram fig. 6, it means that K F is parallel to the zero abscissa line, and is of such a length that it represents $2x$ grammes. Therefore also K F = 2 A B. From this time onwards the levers are continually in motion, and trace a line F E parallel to the theoretical tracing H C, but at such a vertical distance *below* it that the distance represents five times the elongation of R by a load of x grammes. The spring R stops retracting at E, and never returns to its original level, because though it remains under a strain just less than x grammes in value, still this is just too small to make it possible to keep the recording levers in motion until the abscissa line is reached.

Another imperfection which would lead to a blunting of the apex is the presence of "back-lash" in some of the moving joints. There is, in the apparatus, but one joint which could produce this result, viz., the joint at V. This joint has had especial attention paid to it, for the avoidance of such a result.

From these considerations it appears that this experiment forms an excellent test of the accuracy and good working condition of my apparatus. The first and most essential point is that the lines B K and F E of fig. 6 should—if the spring experimented upon is perfect—be straight lines. The fulfilment of this condition proves that the theory of the apparatus is correct. There is, however, a second point to be aimed at, viz., that we should make A B, K F and E C as small as is possible, *i.e.* the friction of the recording apparatus must be reduced to a minimum. A good tracing then should have but little blunting of the apex, and, with a perfectly elastic body, the writing point should return to the zero abscissa line.

There is this, however, to be remembered—and I wish to lay especial stress upon it—that even though there is some flattening of the apex, and some depression of E below C, still the character of the curve is not altered. It is only as if we were limited in our examination to two portions of the theoretically perfect curve A H C, namely, A W and N V. These parts are in every respect identical with B K and F E respectively. By a precisely similar train of reasoning, it follows that the same is true for any tissue experimented upon, just as for a spiral spring.

Study of the Curves Obtained.

In the experiments that I will now describe, muscles from the frog and the rat have been used. I will first take the results obtained from the use of frog muscles, because these have been far more numerous than those from mammalian muscle. For my earlier experiments I selected the frog's sartorius, because its constituent fibres run its whole length, and are parallel to one another. This I considered to be of the greatest importance; for if the fibres run obliquely to one another, a tension impressed longitudinally would produce a lateral movement of the individual fibres, which would produce an increase in the total length over and above that produced by the true lengthening of the fibres—while the latter only is the length we wish to record.

The sartorius, however, is always small, and is very liable to injury during removal; consequently, at Professor Kronecker's suggestion, I adopted a Wundt's preparation (viz., the semi-membranosus and internal rectus). Here the fibres are through the whole length of the preparation nearly parallel to one another, but not so much so as in the case of the sartorius. Here, again, it is not easy to dissect out a preparation rapidly and without injury.

In many of my later experiments I used the gastrocnemius, for I found, on examining a few tracings I made for comparison with those previously obtained from sartorius or Wundt's preparations, that they showed exactly the same characters, and could not be distinguished from the others. As they had the distinct advantage of being prepared quickly and without any injury, I performed many experiments with them.

The error which arises from the obliquity of the fibres is really so small that it may be practically disregarded. This results from a consideration of the following argument: Suppose A B (fig. 7) to represent a muscle fibre, inclined at an angle a to E B, which represents the direction in which weighting of that fibre is carried out. Suppose that, as the result of an increase in load, the muscle fibre is caused to take up a new position C D inclined at an angle a' (less than a) to the vertical E D, and suppose $a = a' + \beta$; then the less A C and B D are the less β becomes. In actual practice A C is very small, and B D varies with the weight put upon the muscle.

If, moreover, α be only a small angle, β becomes still smaller with the same elongation B D. Now, B D is the measurement recorded by our instrument, and from the figure

$$EB = AB\cos\alpha \text{ and } ED = CD\cos\alpha'.$$

Consequently—$BD = CD\cos\alpha' - AB\cos\alpha.$

$$= CD\cos\alpha' - AB\cos(\alpha'+\beta).$$

$$= CD\cos\alpha' - AB\cos\alpha'\cos\beta + AB\sin\alpha'\sin\beta.$$

$$= (CD - AB\cos\beta)\cos\alpha' + AB\sin\alpha'\sin\beta.$$

Now β, as shown above, is always a very small angle, and therefore the error made by taking $\cos\beta = 1$ and $\sin\beta = 0$ is almost infinitesimal. This, therefore, makes $BD = (CD - AB)\cos\alpha'$. Or, if ϵ denote the elongation of the muscle fibre, B D the measurement recorded is equal to $\epsilon\cos\alpha$.

ϵ is the measurement we should wish to record, but if α does not vary much during an experiment, we actually record a constant fractional part of the elongation ϵ.

In examining the tracings that are reproduced below (figs. 8 to 28), I would point out that they are all to be read from left to right; that the descending portion of the curve is produced during the loading of the muscle, and the ascending during the unloading; and that the ordinate, at any point of the curve, is five times the actual elongation of the muscle at that instant.

In all cases the time-marker marks intervals of $\frac{1}{7}$th minute. In each tracing, the preparation, the initial load, if any was used, and the maximum load in grammes are given.

In fig. 8 is given a typical curve: A K is the abscissa line, A E and K F two ordinates. The portion A B is the part traced during loading, the portion B C during unloading, and C D, after unloading is complete, illustrates after-restitution. A E is the total elongation, C L the vertical distance of C above, E F is the total retraction. The difference between D F and C L is the after-retraction, and K D is the residual elongation.

I will discuss these curves under the following headings:—

1. The general characters of the descending portion.
2. The general characters of the ascending portion.
3. The portion of the tracing after the completion of the unloading.
4. The amount of elongation and retraction.

5. The influence of the rate of loading and unloading.
6. The effect of the amount of the load.
7. The effect of tetanus.
8. The mathematical form of the curve.
9. The effect of repeated loadings.

1. *The general characters of the descending portion.*—On studying this part of the curve, we note that in most cases the first piece of the descent is very rapid, and the line traced is nearly straight (figs. 11 and 13). This is especially the case when there is no initial loading (fig. 9). In most cases this is next followed by a curved line, in which the concavity is towards the zero abscissa line. In the early stages of the loading, therefore, the amount of elongation is almost exactly proportional to the stretching weight. This has been previously described by Wundt[1] and v. Wittich[2] for muscle, and by Roy[3] for arterial wall. When the loading passes a certain weight,—and this varies considerably with different muscles,—the extra elongation for an extra increase of a unit of load becomes progressively less and less.

The amount of curving varies considerably both with the rapidity and amount of loading, and also with the particular muscle. There appear to be very considerable differences in different muscles which in no way correspond with their size. The form of curve above described is that which is most frequently obtained, but in several cases it is concave to the abscissa line from its commencement (figs. 8 and 27); in other instances the line is nearly straight throughout (fig. 11). Under certain circumstances, the later portion of the curve may become convex to the abscissa line: this is discussed under the influence of load.

2. *The general characters of the ascending portion.*—On examining the second half of the curve it is seen that throughout it is concave to the abscissa line (figs. 9, 10, 11). The first and larger portion of this piece of the curve is very flattened, while in the terminal piece there is a rapid change, the writing point travelling quickly towards the abscissa line. In other words, this

[1] Wundt, *Die Lehre von der Muskelbewegung*, § 32.
[2] v. Wittich, *Ber. üb. d. Naturf-vers.* 24, Hanover, 1865.
[3] Roy, *loc. cit.*

means that the main part of the restitution occurs during the removal of the last few grammes of load.

3. *The portion of the tracing after the completion of the unloading.*—This terminal piece of the tracing shows a gradual retraction of the muscle, fairly rapid at first, but gradually ceasing until the writing lever comes to rest and traces a line parallel to the abscissa. This line, therefore, gives us a record of the after-restitution, and shows that the main part of this is effected very soon after complete unloading, but that it goes on for some considerable time, becoming progressively less and less in amount. This part of the tracing is convex to the abscissa line.

4. *The amount of elongation and retraction.*—The actual elongation produced varies considerably in different cases: first with the muscle experimented upon, next with the maximum load, and with the rate at which that load is applied. In the series of experiments I have made it has varied from 2 to 8 or 9 millimetres,—see Table I. The amount of retraction, on the other hand, does not vary within such wide limits (from 1 to $2\frac{1}{2}$ mm.). In all the experiments made the muscle never, in the time during which it was watched, shortened so as to reach its original length. As we have previously seen, we must always expect to find a residual elongation, instrumental in origin, and of such a magnitude as would be produced by a weight equal to that which just overcomes the friction of the levers, acting upon the muscle. This is well seen in fig. 5, where a spring has been experimented upon instead of a muscle. In all cases there was a residual elongation far greater in amount than was to be accounted for by this remaining tension. This is readily shown by either of the following two methods. When the experiment is completed we may raise the end of the lever which the muscle supports until the thread 4 is just slackened. In this way all tension is taken off the muscle and we can then record its length. Or, on the other hand, we may start by placing the muscle under a tension equal to that with which it ends, and this is readily accomplished by pulling on the muscle to such an extent that it just retracts slightly on being released. This method has been employed in all the later tracings, *e.g.* in that given in fig. 8. By either of these methods it is found that there is a considerable residual elongation even when the muscle has only been stretched

by a load of 14 grammes (fig. 21). This terminal elongation varies considerably under different conditions, and in the same manner as the full elongation produced. This is well seen in the table given below, where it is seen to vary between ·56 and 6·52 mm. This factor then increases with the load and with the total time of the experiment.

If, having performed an experiment upon a muscle preparation, we then allow it to rest for a few minutes and afterwards repeat the same experiment upon it, we find that the curve produced differs in a few important particulars (figs. 17, 18). The total elongation, the retraction, and the residual elongation are all decreased in amount. This is especially noticeable with the total elongation and the residual elongation, as seen in the numbers in experiments given in the table below.

TABLE I.

No. of Expt.	Preparation.	Time of Loading.	Maximum Load.	Total Elongation.	Total Retraction.	After-Retraction.	Residual Elongation.	
1	Wundt.	$2\frac{4}{7}$ min.	26·55 grms.	8·16 mm.	1·46 mm.	·18 mm.	6·52 mm.	Muscle of R. leg.
2	,,	$\frac{8}{14}$,,	26·55 ,,	4·5 ,,	1·30 ,,	·50 ,,	2·70 ,,	,, L. ,,
3	,,	$\frac{6}{7}$,,	29·22 ,,	4·26 ,,	1·86 ,,	·88 ,,	1·52 ,,	Muscle of R. leg.
4	,,	$\frac{6}{7}$,,	29·22 ,,	3·36 ,,	1·94 ,,	·62 ,,	·80 ,,	Same muscle.
5	,,	$\frac{10}{7}$,,	29·22 ,,	4·90 ,,	1·76 ,,	·74 ,,	2·40 ,,	Muscle of L. leg.
6	,,	$\frac{10}{7}$,,	29·22 ,,	3·46 ,,	1·76 ,,	·80 ,,	·90 ,,	Same muscle.
7	,,	[illegible] ,,	29·22 ,,	4·58 ,,	2·08 ,,	·24 ,,	2·26 ,,	Muscle of R. leg.
8	,,	$\frac{10}{7}$,,	29·22 ,,	2·64 ,,	1·90 ,,	·18 ,,	·56 ,,	Same muscle.
9	,,	$\frac{12}{14}$,,	29·22 ,,	3·42 ,,	1·66 ,,	·32 ,,	1·44 ,,	Muscle of L. leg.
10	,,	[illegible] ,,	29·22 ,,	3·00 ,,	1·76 ,,	·54 ,,	·70 ,,	Same muscle.
11	Sartorius	$\frac{8}{14}$,,	14·61 ,,	3·60 ,,	2·20 ,,	·60 ,,	·80 ,,	Muscle of R. leg.
12	,,	$\frac{12}{14}$,,	14·61 ,,	6·60 ,,	2·36 ,,	·60 ,,	3·64 ,,	Muscle of L. leg.
13	Gastrocnemius	$\frac{8}{14}$,,	14·61 ,,	2·76 ,,	1·28 ,,	·52 ,,	·96 ,,	Muscle of R. leg.
14	,,	$\frac{6}{7}$,,	14·61 ,,	3·00 ,,	1·20 ,,	·40 ,,	1·40 ,,	Muscle of L. leg.

In the above table the measurements given in millimetres are those of the muscle itself, and are obtained by dividing the measurements of the tracings by 5. These are given as a few typical measurements which have been taken of a great number of tracings.

The experiments are given in pairs, each pair being taken from the same frog, thus forming a preparation from either leg.

5. *The influence of the rate of loading and unloading.*—Where a spring is experimented upon instead of a muscle we see that a difference in rate produces no difference in the tracings obtained (figs. 5^A, 5^B), though we know that a metal spring does not take up its final position of elongation instantly, but continues to increase in length for some time. This after-elongation is, however, in this instance, a very small proportion of the total elongation, and with the magnification adopted in my apparatus would not be detected. Consequently the two curves are identical. With muscle, on the other hand, a varying rate of loading produces marked differences in the curves obtained. The more rapidly the loading is effected the less are the total elongation and the residual length, whilst the retraction tends to increase (Table I.—Experiments 1 and 2 and figs. 12, 13). In many cases, too, the character of the curve is different, the alteration being mainly confined to that portion of the curve traced during loading. With the increase of rapidity the curve tends to become straightened out until in some cases the line traced is nearly straight (figs. 12, 13).

A second difference commonly observed is that as the rate becomes slower the descending portion of the curve becomes steeper. This is especially noticeable with the earlier part of the descent. This means that with small loads the after-extension is well marked and occurs rapidly, but as the load increases the after-extension diminishes in amount, for the curve becomes more concave as compared to one in which the rate of loading is rapid.

The characters of the second portion of the curve are, as a rule, but slightly altered. The longer the muscle has been under strain the less the total retraction becomes, *i.e.* the less able it is to recover itself.

The residual lengthening is always increased by prolonging the time of the experiment, and in some cases this is very marked (Table I.—Experiments 1, 2 and 11, 12, figs. 12, 13, 14, 15).

6. *The effects due to the alteration of the maximum load.*—As above indicated, the more the load is increased the more concave the curve becomes. The inclination of the terminal part to the zero abscissa line becomes more and more acute. This is much

more marked with some muscles than with others, and, as a rule, it is best shown with strong muscles.

When the load is increased beyond these limits the curve next becomes convex to the zero abscissa line, and then shortly afterwards the muscle is ruptured (fig. 19). In all the cases in which I have produced this effect, the muscle fibres were torn through at about their middle, not at one end, nor near the insertion into tendon. This change in the curvature of the tracing is well known, having been described by Marey[1] for muscle, and by Roy[2] for arterial wall, and means that for the time it is being traced increase of successive units of weight produces elongations which gradually increase. This is the very reverse of that which occurs during the previous portion of the tracing.

Another character brought out by varying the maximum load is, that the greater the strain under which the muscle is placed, the less capable does it become to retract thoroughly. The greater, then, is the residual lengthening. Kronecker has shown that if the load for a Wundt's preparation exceeds from 14 to 16 grammes, the muscle, when relieved of its load, will not retract completely.

7. *The effect of tetanus.*—The method I employed to study the effect of tetanus was to make two muscle preparations from opposite limbs of a frog. One of these was then fixed in position, and the position of the writing point indicated by making it mark a short horizontal line at that point. It was then tetanised directly, and the loading and unloading rapidly carried out. The second preparation was then fixed in position, and the writing point brought to the same position it occupied at the commencement of the experiment upon the first preparation. The tracing was then taken at the same rate as in the previous case. Examples of these curves are given in figs. 20, 21, 22, and measurements of several curves are given in Table II.

In all cases it is to be noticed that the curves both of loading and unloading are steeper in the tetanised muscle than in the corresponding muscle at rest. In other words, a tetanised muscle is stretched more by a given weight than a corresponding muscle at rest. In a tetanised muscle there is, as a rule, only slight after-retraction. Residual elongation is well marked.

[1] Marey, *loc. cit.*

[2] Roy, *loc. cit.*

TABLE II.

No. of Expt.	Preparation.	Time of Loading.	Maximum Load.	Total Elongation.	Total Retraction.	After-Retraction.	Residual Elongation.	Amount of Shortening on Tetanising.
1	Gastrocnemius	$\frac{4}{7}$ min.	31·55 grms.	2·00mm.	·80mm.	·2 mm.	1·00mm.	
2	,,	$\frac{4}{7}$,,	31·55 ,,	6·56 ,,	2·60 ,,	·0 ,,	3·96 ,,	5·2 mm.
3	,,	$\frac{6}{7}$,,	31·55 ,,	2·68 ,,	·80 ,,	·2 ,,	1·68 ,,	
4	,,	$\frac{6}{7}$,,	31·55 ,,	5·60 ,,	2·44 ,,	·0 ,,	3·16 ,,	2·92 ,,
5	,,	$\frac{2}{7}$,,	14·61 ,,	4·20 ,,	1·20 ,,	·70 ,,	2·30 ,,	
6	,,	$\frac{2}{7}$,,	14·61 ,,	6·10 ,,	1·88 ,,	·62 ,,	3·60 ,,	7·7 ,,
7	,,	$\frac{12}{14}$,,	14·61 ,,	2·92 ,,	1·24 ,,	·44 ,,	1·24 ,,	
8	,,	$\frac{13}{14}$,,	14·61 ,,	11·40,,	1·80 ,,	·84 ,,	8·76 ,,	8·1 ,,

An interesting tracing, in illustration of Weber's paradox, is given in fig. 22. Here, after a certain load (about 12 grms.) had been added, the actual length of the tetanised muscle became greater than that of the untetanised muscle, as shown by the crossing of the two descending curves. It will be further noticed that the two ascending curves cross very late in the experiment, viz., when the load was about 4 grammes. Hence, an over-weighted tetanised muscle does not recover itself so quickly as a corresponding muscle which has not been tetanised. The load in this case was only 14 grammes, but still it appeared to be too heavy for those particular muscles, which were poorly developed.

8. *The mathematical form of the curve.*—Wertheim[1] describes the curve of loading as being an hyperbola. He arrives at this conclusion by first taking, by a cathetometer, two measurements of the elongations produced by the smallest, and greatest weights employed. He then calculates what the intermediate elongations should be from the formula $y^2 = ax^2 + bx$, and compares them with the actual elongations observed. He found that the observed and calculated values were fairly concordant. For this investigation human muscles obtained four or five days after death were employed. The curves obtained during unloading were not investigated. Roy, experimenting upon arterial wall, did not at first consider that his curves had any common

[1] Wertheim, *Ann. de Chemie et Physiologie*, 3, xii. p. 385. 1841.

mathematical form,[1] but later stated that a careful examination showed them to be hyperbolas.[2] Here, again, the curves produced during unloading were not investigated.

In this second paper Roy gives a figure in support of his contention that the curves he obtained by his method from arterial wall are hyperbolas. In that figure are drawn three different sets of parallel lines. Three lines are drawn, which meet exactly in a point on the convex side of the curve. Each one of these three lines is stated by him to bisect all the parallel lines in one of the series. If this were actually true the curve would be an hyperbola. If, however, we take a pair of compasses and measure the lines, we find that not a single one of them is bisected, and some of them are out by as much as $\frac{1}{8}$ of an inch. It is completely misleading, then, to be told, on the faith of that figure, that the curve of extensibility of arterial wall is an hyperbola.

The method I have employed to determine this point for my curves has been the following:—An enlargement of each curve was first obtained by means of a pantograph. A series of parallel straight lines is then drawn in the curve, and each of the lines bisected. The same is repeated for two other series of lines. If the curve thus treated is a conic section, the centres of a series of parallel straight lines lie in a straight line, and in this way we should get three straight lines. Now, if these three straight lines meet in a point, the curve is proved to be a conic section. If the point lies on the convex side of the curve, it is an hyperbola; if on the concave side, it is an ellipse; and if at an infinite distance away,—*i.e.*, if the three straight lines are parallel to one another,—it is a parabola.

On treating my curves in this manner, I found that in all cases the conditions broke down at once, for the centres of the three series of parallel straight lines did not lie in three straight lines. Further, in most cases they did not even approximate to this condition. In four cases I found that the conditions were approximately fulfilled. In two of these cases the curves were nearly hyperbolas, in one an ellipse, and in the fourth a parabola. All these instances occurred in the second part of the tracings, viz., that produced by the unloading of the muscle.

[1] Roy, *Journ. Phys.*, vol. iii.

[2] Roy, *Journ. Phys.*, vol. ix.

In no instance was a curve of loading found to be a conic section.

Seeing how rare these positive results were, I am inclined to consider them accidental, especially as they all were only approximately correct.

Purely negative results were also obtained for tetanised muscles, and, as mentioned later, for the curves obtained under various conditions from mammalian muscle.

I have attempted to find a simple mathematical curve that these curves might represent, but as yet without any success.

9. *The effect of repeated loadings.*—Previous experiments having shown that a repetition of an experiment upon the same muscle after a short rest produced a different curve, I proceeded to study the effect of loading it several times. This was effected in the following way:—The muscle being adjusted, the writing point was made to draw a short abscissa line, which thus marked the original length of the muscle. The writing surface being kept at rest, the muscle was next loaded, and thus a vertical line was traced which gave the total elongation. The writing surface was then moved by hand through a short distance and the muscle then unloaded. In this way another vertical line was drawn, this time towards the zero abscissa line. This gave the total retraction. The writing surface was again moved, a short horizontal line being drawn, and then, after-retraction was allowed to occur, a third vertical line being thus drawn. When retraction had ceased, another horizontal line was drawn by moving the writing surface, and the experiment repeated. In this way fig. 23 was produced. On studying it we see that with the load employed, 17·7 grammes, the muscle did not, after the first loading, retract to its original length. On loading a second time the total elongation produced was less than before, but the length of the muscle was greater than its length when measured in the corresponding stage of the first loading. The total retraction on the second loading was less than on the first loading, but a greater proportion when compared with the total elongations in the two cases.

After-retraction was also well marked and the muscle returned better towards the length it had before the commencement of the second loading. The next few loadings showed the

same points as they were repeated, the muscle no longer tended to stretch beyond a certain point, and after-retraction brought the muscle nearly back (in some cases quite back) to its length before that particular loading. The time of loading and unloading in these experiments was two seconds for each. Thus, after a time, further repetition of the experiment produced simply a repetition of the tracing previously obtained. By this process, then, the muscle is brought into such a condition that addition of a certain load always produces a definite elongation, removal of the load a definite retraction, and then after-retraction brings it back to its previous length.

Fig. 24 is essentially a similar tracing, only the writing surface was kept in motion during alternate loadings.

EXPERIMENTS UPON MAMMALIAN MUSCLE.

The muscles of the rat were in all cases employed, the gastrocnemius and soleus being dissected out and used. On examining the tracings obtained (examples of which are given in figs. 25 to 28) it is seen that the general form of the curve, under all the conditions employed, is very much the same as in corresponding curves obtained from frog muscles. Measurements of some of these tracings are given in Table III.

The curvature of the portion obtained during loading tends, on the whole, to be more uniform than is the case in the curves obtained from frog muscle; but sometimes the latter portion of this part of the tracing is nearly a straight line. In the curve produced during unloading we note that, just as was the case with frog muscle, the main part of the retraction occurs as the last few grammes of tension are being removed from the muscle.

Other points of similarity observed are that a slower rate of loading also produces a steeper curve and a greater total elongation. At the same time, the residual elongation becomes greater. (*Cf.* Experiments 3 and 4 with Experiments 5 and 6, Table III.)

Again, where an experiment is repeated upon the same muscle after a short period of rest we find, as with the frog muscle, that the total elongation is less than before, and the residual elongation less. In all other particulars there is no

TABLE III.

No. of Expt.	Time of Loading.	Maximum Load.	Total Elongation.	Total Retraction.	After-Retraction.	Residual Elongation.	
1	$\frac{5}{7}$ min.	70·5 grms.	5·7 mm.	3·24 mm.	·8 mm.	1·66 mm.	Muscles of R. leg, nerves intact.
2	$\frac{5}{7}$,,	70·5 ,,	6·4 ,,	3·68 ,,	·52 ,,	2·2 ,,	,, L. ,, cut.
3	1 ,,	44·25 ,,	5·0 ,,	2·8 ,,	·6 ,,	1·6 ,,	Muscles of R. leg dissected out, nerves and vessels cut.
4	1 ,,	44·25 ,,	5·16 ,,	2·8 ,,	·6 ,,	1·76 ,,	Repetition on same.
5	$\frac{3}{7}$,,	44·25 ,,	5·18 ,,	3·2 ,,	·6 ,,	1·38 ,,	Muscles of L. leg in same way.
6	$\frac{3}{7}$,,	44·25 ,,	4·44 ,,	3·2 ,,	·6 ,,	·64 ,,	Repetition on same.
7	$\frac{5}{7}$,,	70·5 ,,	6·0 ,,	3·32 ,,	·68 ,,	2·0 ,,	Muscles of R. leg, nerves intact.
8	$\frac{10}{7}$,,	70·5 ,,	7·6 ,,	3·4 ,,	·6 ,,	3·6 ,,	Muscles of L. leg, nerves cut.

essential difference between the two tracings obtained from the two kinds of muscle.

The mathematical form of either half of the tracing was in no case found to approximate to a conic section.

There is one class of experiment that remains to be described, viz., where the nerve to the muscle is still intact and the animal under an anæsthetic. Morphia and ether were in all cases the anæsthetics employed. In the tracings obtained the following points are to be noticed:—If the nerve is still intact the tracing is less steep and retraction better, the residual elongation being diminished (*cf.* figs. 26 and 27). Thus a muscle with its nerve intact elongates less readily and retracts better after loading than one in which the nerve has been cut. In a few cases, after the retraction occurring during unloading has ceased, the muscle still keeps retracting, not in the ordinary way that after-retraction is usually effected, but by fits and starts. In these cases the muscle retracts to nearly its original length (fig. 28).

Further work upon this subject, which I hope to publish shortly, consists of a study of the extensibility of mammalian muscle, and of other tissues under various conditions.

In conclusion, I wish to express my gratitude to Professor Halliburton and Mr E. F. Herroun for the kindly advice and criticism with which they have aided me during the progress of this research. To Mr A. T. Hare I am also much indebted for his kindness in reading through and criticising the more mathematical portions of this paper.

[The expenses of this research have been mainly defrayed by grants from the Scientific Grants Committee of the British Medical Association.]

EXPLANATION OF PLATES VI. AND VII.

PLATE VI. FIGS. 1, 2, 3, 4, 6 and 7, are explained in the text, pp. 368 *et seq.*

PLATE VI. FIG. 5A. Curve obtained from a steel spring. Max. load, 29·22 grms. Time of loading, $\frac{5}{14}$ min. Tracing to be read from left to right.

FIG. 5B.—Similar to 5A except time of loading, which was $\frac{5}{7}$ min.

FIG. 8.—Gastrocnemius and Soleus of a Rat taken immediately after death. Max. load, 44·25 grms. Time of loading, 1 min. This is the tracing from which were taken the measurements given in Expt. 4, Table III.

FIG. 9.—Gastrocnemius of Frog. Max. load, 26·55 grms. Time of loading, $\frac{3}{7}$ min.

FIG. 10.—Wundt's preparation. Max. load, 26·55 grms. Time of loading, 3 min. This is a second experiment taken upon this muscle.

FIG. 11.—Sartorius. Max. load, 22·12 grms.

FIG. 12.—Wundt's preparation. Initial load, 5 grms. Max. load, 31·55 grms. Time of loading, $\frac{2}{7}$ min.

FIG. 13.—Wundt's preparation of opposite leg to fig. 12. Same loading. Time of loading, $\frac{18}{7}$ min.

FIG. 14.—Wundt's preparation. Initial load, 2 grms. Max. load, 29·22 grms. Time of loading, $\frac{13}{14}$ min. The tracing from which the measurements of Expt. 9, Table I. were taken.

FIG. 15.—Wundt's preparation. From this are obtained the figures in Expt. 7, Table I.

FIG. 16.—Same muscle as in fig. 15. Measurements given in Expt. 8, Table I.

PLATE VII. FIG. 17.—Wundt's preparation. See Expt. 6, Table I.

FIG. 18.—Same muscles as fig. 17. See Expt. 5, Table I.

FIG. 19.—Sartorius. This muscle ruptured during loading, and when the load had reached 31·42 grms.

FIG. 20.—Gastrocnemius. Lower tracing from untetanised R. muscle, upper from tetanised L. muscle. Indirectly tetanised. This shows the irregularity of the curve during and after unloading, which I often obtained when tetanisation was indirect.

FIG. 21.—Gastrocnemius. Lower tracing from untetanised L. muscle, upper from tetanised R. muscle. Directly tetanised. Both muscles started at the level A; when the R. muscle was tetanised it reached the height B. Measurements in Expts. 5 and 6, Table II.

FIG. 22.—Gastrocnemius. Measurements in Expts. 7 and 8, Table II

FIGS. 23 and 24.—Repeated loadings and unloadings of Wundt' preparation as described in text, p. 386.

FIG. 25.—Rat's muscle. See Expt. 6, Table III.

FIG. 26.—Rat's muscle, R. leg. Nerve and blood-vessels intact. Rat anæsthetised. Expt. 7, Table III.

FIG. 27.—Same Rat as in fig. 26, but nerve and vessels cut and L. leg employed. Expt. 8, Table III.

28.—Similar experiment to that in fig. 26. Initial load, 0·0 grms. Max load, 88·125 grms.

THE SEMILUNAR FIBRO-CARTILAGES AND TRANSVERSE LIGAMENT OF THE KNEE-JOINT. By HUBERT HIGGINS.

(Communicated to the Anatomical Society, Feb. 13, 1895.)

IN this paper I continue the record of the variations of the knee-joint,[1] describing those of the semilunar cartilages and transverse ligament, with a few remarks on some functions of these structures.

Each of the semilunar cartilages consists of a strong basis of bundles of fibrous tissue continuous from one extremity to the other; they are chondrified on their concave superior and plane inferior surfaces; the former is coated much more thickly than the latter.

The extremities show the fibrous tissue basis arranged in rounded bundles uncovered with cartilage.

A. THE EXTERNAL SEMILUNAR CARTILAGE.

1. *The anterior cornu.*—The fibrous extremity having grooved the tibia in front of the external spine, is attached at the

side of the anterior crucial ligament; as the average antero-posterior length of the tibial attachment of the anterior crucial

[1] See *Proc. Anat. Soc.*, Nov. 1894, p. v, for an account of the varieties of the posterior crucial ligament, *Journal of Anatomy and Physiology*, Jan. 1895.

is 1·70 cm., and that of the anterior cornu less than 1·00 cm., it may be attached to a surface corresponding to its anterior, its posterior, or its middle part.

In about 10 per cent. of cases some of the fibres (in one case as many as one-third) are anterior to those of the anterior crucial ligament, and are attached outside the antero-external elevation of the internal articular surface. In two cases a strong band of fibres, derived from the vastus externus, are found to be directly continuous with the anterior cornu of the external semilunar, and attached with them to the tibia in the usual situation.

The average length of the fibrous part of the anterior cornu is about 1·70 cm.

2. *Posterior cornu.*—Usually about one-third of its fibres constitute Humphry's ligament (though, in one case, nearly all are attached to the femur). A few of the fibres of this ligament, though apparently primarily derived from the post cornu, may have a secondary tibial attachment. The remaining fibres fit into a groove posterior to the external spine, and are attached either to a roughened surface behind the spine, to the inter-articular space between the attachment of the crucial ligaments, or to the outside of the internal spine. The number of fibres allotted to each attachment varies considerably in different specimens. In a few cases the fibres reached as far forwards as the side of the anterior crucial, and may be intimately connected with its fibres. The fibres of Wrisberg's ligament, and commonly the outermost fibres of the oblique portion of the posterior crucial, are continuous with the bundles of fibrous tissue in the posterior cornu.

The average length of the fibrous portion is about 1·60 cm.

B. The popliteus muscle is invariably very intimately connected with the external semilunar. The following are the commonest varieties:—

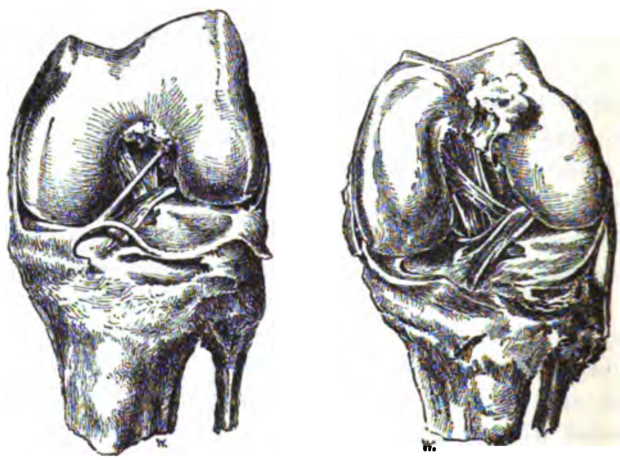
1. Directly, by means of fibres continued from the tendon, either posterior to or anterior to (uncommon) the popliteal groove on the cartilage.

2. Certain horizontally-disposed fibres, passing to the posterior crucial ligament from the popliteus, are intimately connected with the post cornu.

3. There may be a strong portion of the capsule connected with the superficial part of the tendon, and firmly connected with the cartilage anterior to the groove.

4. The posterior cornu, the popliteus, and the external semilunar may be connected by some dense irregularly arranged fibres which fill up the interval between them.

5. In a few cases a strong band of fibres, forming part of the ligamentum posticum Winslowii, attached above near the insertion of the popliteus, and below to the tibia external to the tibial attachment of the post crucial, is firmly connected with the popliteus and the external semilunar.



I have two specimens that, with the exception of a small ovoid deficiency, the size of a split pea, are complete interarticular fibro-cartilages.

C. Internal Semilunar Cartilage.

1. *Anterior cornu.*—The fibres composing the anterior cornu of the internal semilunar cartilage groove the antero-external extremity of the articular surface, and are attached to a rough surface of bone immediately external to the depression. In one or two specimens the fibres are found to be continuous with those of the anterior crucial ligament. In one specimen nearly half of the anterior cornu is chondrified, and is attached to the

femur about half-an-inch from the attachment of the anterior crucial.

The average length of the fibrous portion is 1·60 cm.

The long fibrous anterior cornu is, I think, accounted for by the fact that it does not come into contact with the femur; its direction (downwards, forwards, and outwards), and the extremely short coronary ligament, being sufficient evidence that it is not for the purpose of permitting movement of the internal semilunar cartilage.

In one of my specimens the anterior cornu of the internal semilunar divides into two unequal divisions, one-third passing directly upwards and outwards to be attached by spread-out fibres immediately beneath the posterior crucial, and half-an-inch above the femoral attachment of the anterior crucial. The remaining two-thirds are attached in the usual manner.

There are three other specimens in which fibres from the anterior cornu of the internal semilunar pass to be attached to the femur.

2. *The posterior cornu* grooves the bone behind the internal spine, and is attached usually anterior to the straight portion of the posterior crucial ligament, and behind the internal spine of the tibia. In one or two specimens it is attached at the side of the straight portion of the posterior crucial ligament.

The internal semilunar is connected for about 3·00 cms. with a strengthened roughly triangular part of the true capsule, immediately under the internal lateral ligament.

The average length of the fibrous portion is ·50 cm.

The semilunar cartilages resemble each other in their structure and their connection with the capsule, both having strengthened portions of the capsule attached near the internal and external lateral ligaments respectively. Both anterior cornua occasionally have fibres continuous with those of the anterior crucial ligament. They differ from each other in the following particulars:—

External Semilunar.	Internal Semilunar.
The space between the cornua.	
(1.) Less than 1·00 cms.	(1.) More than 3·00 cms.
The length of the coronary ligaments.	
(2.) In front, more than 2·00 cms. Behind, ... 1·30 „	(2.) In front, ... ·50 cm. Behind, ... ·40 „
The width of the cartilage.	
(3.) In front, ... 1·00 cms. The centre, ... 1·25 „ Behind, ... 1·20 „	(3.) In front, ... ·50 „ The centre, ... ·80 „ Behind, ... 1·40 „
The length of the fibrous extremities of the cornua.	
(4.) Anterior, ... 1·70 cms. Posterior ... 1·60 „	(4.) Anterior, ... 1·60 „ Posterior, ... ·50 „
Mobility of cartilages in dissected specimens.	
(5.) Anterior cornu, 1·25 cms. Posterior cornu (antero-posterior movement), 1·00 „ Lateral movement, 1·10 „	(5.) Anterior cornu, 0·80 „ Posterior cornu, 0·65 „ Lateral movement, 0·45 „
(6.) Strong, thick, and uniformly wider. Forms a concavity for the support of the condyle on the concavo-convex external articular surface of the tibia.	(6.) Thinner, and narrow in its anterior; two-thirds thicker behind. Serves to deepen the bi-concave internal articular surface.
(7.) The posterior cornu is invariably attached to the femur by Humphry's ligament, and occasionally by Wrisberg's ligament.	(7.) The anterior cornu is occasionally attached to the femur by a defined band of fibres.
(8.) Comparable to the temporo-mandibular interarticular fibro-cartilage, and like it is occasionally almost complete.	(8.) Resembles the glenoid ligament.
(9.) It is intimately connected with the popliteus and posterior crucial.	(9.) Very rarely connected with posterior crucial.
(10.) The existence of the popliteal groove on the cartilage, with the consequent modifications of the capsule.	

In two specimens the external semilunar cartilages are almost complete interarticular fibro-cartilages, with small ovoid deficiencies immediately outside the external spine.

In another specimen a flattened, rounded, tongue-shaped process of fibro-cartilage projects from about the centre of the concavity of the cartilage; anterior to it the cartilage presents a normal appearance. But posteriorly the fibres are not chondrified, being covered by a rugous membrane.

Running directly downwards from the ligamentum posticum is a strong band of fibres mingled with the fibres of the tibial attachment of the posterior cornu of the interior semilunar.

On the inferior surface of the cartilage there is a sharp fold of tissue between the projection of the posterior part of the cartilage. Anterior to the fold the fibres are more exposed and roughened, possibly from the effects of chronic rheumatoid arthritis.

The most conspicuous features of the external semilunar cartilage are its mobility and its intimate connection with the popliteus, and the invariable attachment of its posterior cornu to the femur.

Its mobility is shown by the character of the articular surfaces, the flexible and approximated cornua in which the fibrous extremities are much longer than the internal, the length of the coronary ligament and its freedom of movement in the dissected joint.

In extension of the joint the anterior part of the cartilage is grasped between the semilunar depression on the external articular surface of the femur and a groove on the antero-internal extremity of the external articular surface of the tibia.

During flexion the cartilage with the outer condyle glides backwards along a curved groove on the tibia till it reaches the smooth convex surface at its posterior extremity.

The agents concerned in this movement when the tibia is fixed are :—

1. The popliteus acts much in the same way as the external pterygoid does, dragging the external semilunar as well as the outer condyle backwards.

It is not by any means clear during which period of the act of flexion the popliteus acts: the shape and direction of the

groove for the tendon on the femur would lead one to imagine that it occurred during semi-flexion.

2. The sartorius and the semi-tendinosus, acting downwards and inwards, would, when the tibia and the hip-joint are fixed, tend to cause an outward rotation of the femur, or on account of the conformation of the articular surfaces, to impart a backward gliding movement to the outer condyle.

3. In the semi-flexed and the flexed condition, especially when the leg is supporting the weight of the body, the tense quadriceps extensor femoris would cause a considerable pressure on the larger and outer side of the trochlea through the patella.

4. The femoral attachment of Humphry's ligament is moved forwards during flexion, and so pulls on the posterior part of the external semilunar (hauling in the slack), and so preventing the flexible posterior cornu from being wrinkled.

The popliteus having its main attachment to the internal border of the tibia under the internal lateral ligament, when it acts from the femur causes an internal rotation of the tibia, so as to produce the same result as if it acted from the tibia, and caused the femur to rotate outwards.

In a similar fashion, the sartorius and the semi-tendinosus would cause an inward rotation of the tibia.

I have a number of observations to record on the articular surfaces of the femur and tibia and the popliteus, which throw more light on the subject of the mechanism of the knee-joint: I therefore refrain from further discussion on this question at present.

D. The Transverse Ligament.

The transverse ligament is extremely variable: in 25 per cent. of cases it is absent; in 4 per cent. it is represented by a membrane; in 10 per cent. it is a fine glistening bundle of fibrous tissue; in 15 per cent. it is a well-marked, rounded, and strong bundle of fibres. The remaining specimens present unimportant variations.

The more superficial fibres of the anterior cornu of the internal semilunar separate about 1·60 cm. from the tibial attachment to form the transverse ligament; they pass directly to be continuous

with the outermost fibres of the anterior cornu. External semilunar 1·60 cm. from its tibial attachment.

In four specimens that were well-marked instances of a septal ligamentum mucosum, the fibres constituting the transverse ligament were derived from the anterior cornu, and the internal semilunar sends a contingent to be attached to the interarticular space internal to the straight portion of the posterior crucial ligament.

With the exception of the transverse portion, these fibres were enclosed in the ligamentum mucosum.

In one specimen the transverse ligament is derived from the vastus externus, which is also connected with the external semilunar.

Specimen of Multiple Transverse Ligament.

The anterior cornu of the internal semilunar is divisible into two distinct portions:—

1. A deep part, attached in the usual manner to the tibia.

2. A superficial part, which consists of five distinct bundles of fibres, which are attached to the anterior cornu. External semilunar.

(i.) Three of these unite to form a single strong, rounded bundle attached to the periphery of the external semilunar; some of the fibres are apparently continuous with that part of the capsule connected with the popliteus.

With the exception of deepest bundle of fibres, they all receive fibres from the tibial attachment of the vastus internus.

(ii.) On a deeper and lower plane is a flattened bundle of fibres which sends

(*a.*) A strong bundle of fibres to be continuous with the anterior cornu of the internal semilunar.

(*b.*) A few fibres connected with (i.).

(iii.) A peripheral bundle, derived directly from the vastus internus.

There can be no question that the transverse ligament *per se* is an extra-capsular structure contained in the sub-patellæ Haversian gland, superficial to the true capsule. Its variability

and its occasional connection with the accessory capsule points possibly to an extra-capsular origin.

But this, and the significance of occasional connection of the semilunar cartilages with extra-capsular structure, can only be

explained by a careful definition of the true capsule of the knee-joint in a large number of specimens, and the investigation of the joint embryologically, and in animals.

ARE THE EXTRINSIC MUSCLES OF THE AIR-BLADDER IN SOME SILUROIDÆ AND THE "ELASTIC SPRING" APPARATUS OF OTHERS SUBORDINATE TO THE VOLUNTARY PRODUCTION OF SOUNDS? WHAT IS, ACCORDING TO OUR PRESENT KNOWLEDGE, THE FUNCTION OF THE WEBERIAN OSSICLES? A CONTRIBUTION TO THE BIOLOGY OF FISHES.

By WILLIAM SÖRENSEN, Copenhagen.

(*Continued from page* 229.)

II.

WHAT IS, ACCORDING TO OUR PRESENT KNOWLEDGE, THE FUNCTION OF THE WEBERIAN OSSICLES?

The Theory of Weber.

WHEN, in his celebrated work[1] on the ear of the aquatilia, Weber made known to the learned world the ossicles, which bear his name, he showed that they connect part of the ear with the air-bladder, which he regards as an organ serving to intensify the sounds that strike the body of the fish, while, according to him, the ossicles are the conductors of the sound to the ear.

A. *Objections urged against the theory of Weber* (with exception of that one, on which Professor Hasse has founded his theory).

Sagemehl, it is true, says (IV. p. 14) that the interpretation of Weber of the function of these ossicles "is now generally abandoned," and, in return, he sets up another, which is a modification of a theory propounded by Professor Hasse some years before. As I shall subsequently have occasion to refer to these theories at some length, I need now only say that I have not succeeded in finding any reason suggested by Sagemehl and Hasse, by virtue of which Weber's theory ought to be aban-

[1] XVII.: Weber, E. H., "De aure et auditu hominis et animalium. Pars I. De aure animalium aquatilium," Lipsiæ, 1820. 4to.

doned. As Professor Bridge and Haddon have collected all the objections set forth against the theory of Weber—*with the exception of one, however, that one upon which is founded the theory of Hasse, which they mean to have adopted*—and as, moreover, they have urged new objections against it, it may not be out of place to examine the reasons set forth by these two authors. I take the liberty to quote the said objections in an order somewhat different from that in which they are found in their work.

1. *On the capacity of hearing of the Ostariophyseæ, and the habits of the Siluroidæ* Professors Bridge and Haddon say (*Ib*, p. 276):

"(2.) Contrary to what might fairly be expected, if so complicated a structure as the Weberian mechanism is an accessory to hearing, there is absolutely no evidence of the existence of exceptional powers of hearing, either in the Siluridæ or any other Ostariophyseæ."

This, certainly, cannot be called sound reasoning, as, in fact, this objection only is due to an ignoring whether the animals in question are sharper of hearing than fishes in general or no. It would have been quite different, if the authors had been able to state that this is not the case. I willingly agree that we have no absolute evidence of the Ostariophyseæ being sharper of hearing than other fishes. But, in truth, do we know much about the intellectual faculties or the senses of the fishes? Not many years ago, we were generally told, in manuals of Zoology, that the fishes were unable to move the eyes, a thing which, however, they do with as much facility as the higher vertebrates.

I must point out, however, that on different grounds, it may reasonably be supposed that the Ostariophyseæ—and particularly the Siluroidæ—are sharper of hearing than most other fishes. It is a well-known fact that when in a species, genus, family, one sense is less developed, then one or more of the remaining senses are in return more developed. Now fresh water is also less transparent than the water of the ocean, nay, it is often more or less opaque. (I do not ignore the existence of freshwater lakes with limpid water, *f.i.* in Switzerland; such lakes, however, form an exception from the common rule. Nor is the *depth* of the limpid lakes in Switzerland inhabited by Ostariophyseæ, but by Salmonoids.) And which fishes are

inhabiting the fresh waters? Not being a systematic Ichthyologist myself, I may take the liberty to refer to one, whose ability in this respect is open to no objection. Dr. Günther (XIII. p. 216) says: "The two families, Cyprinidæ and Siluridæ, of which the former yields a contingent of one-third, and the latter of one-fourth of all the fresh-water species known of our period . . ." Let us add that in this case, the Characini[1] yield more than one-tenth of all the freshwater species, so that these three families of the Ostariophyseæ—apart from the family of the Gymnotini, which counts only a few species—make more than two-thirds of all the freshwater species. Now the great majority of our Cyprinoidei live at the bottom of shallow waters along the shore, and as to most of the Characini which I have seen in Rio Parana and Rio Paraguay, I venture to say, that they resort, at any rate most frequently, to the surface of the rivers, while in these rivers the Siluroidæ (about the biology of which I am going to impart some particulars) when grown up, never[2] rise to the surface of the water, but remain at or near the bottom. And is the above-mentioned general rule to be regarded as a mere postulate with regard to the fishes? About *Amblyopsis spelæus*, the blind viviparous Fish in the Mammoth cave, Tellkampf says[3]: "The hearing of the fish is very acute." (Let me add, by the way, that if the description of the air-bladder in this fish, given by the same author,[4] is correct—and having had an opportunity, in another case, to be convinced of the accuracy of this author, I do not doubt it—it is unquestionably an organ of sound. The blind *Lucifuga subterranea*, that inhabits the subterranean cavities of Cuba, also appears to be in possession of an air-bladder serving

[1] Günther (XVI. vol. v.) enumerates 544 species of Siluroidæ and 229 species of Characini.

[2] Only once, in Riacho del Oro, whose waters are not so opaque as those of Rio Paraguay, I have seen a Siluroid (*Pseudaroides clarias*) in the surface of the water. But that fish was sick to such a degree, that while swimming I was able to overtake it and seize it with a hook.

[3] *Ann. a Mag. o. Nat. Hist.*, Vol. XIII., London, 1844, p. 112.

[4] Tellkampf, Th. G.: Über den blinden Fisch der Mammuthshöhle in Kentucky. . . . (*Joh. Müller's Arch. f. Anat. u. Phys.*, Berlin, 1844, pp. 381-394). The description of the air-bladder by this author is quoted in my *Lydorganer hos Fiske*, p. 128.

as a sound-producing organ, if we are to judge from the description of Poey.[1]

Day ("Instincts and Emotions in Fishes," *loc. cit.*, p. 42) says on freshwater fishes, without entering into details however: "At many temples in India fishes are called to receive their food by means of ringing, or by musical sounds." And (*ibid.*, p. 43) he refers to a fish, which "most probably . . . was a Rita" (a genus belonging to the Siluroidæ): "The Fakeers of the place call them together; but they are not much disposed to come for mere calling, seeming to require more substantial proof of being wanted in the shape of food."

And, besides, ask the first angler you meet, and he will tell you that when you are angling for pike and fishes belonging to the Salmonoidei, you must be more careful not to be seen than when you are angling for fishes belonging to the Cyprinoids, but, in return, when you go out angling for the latter (as well as for eels) you must particularly mind not to make a noise, a precaution much more wanted with these fishes than with the first-mentioned. I confess that I was very much surprised when for the first time in the Argentine Republic I saw a native angling. Before throwing out his (very primitive) line, he began beating the surface of the water repeatedly with slight strokes of the thin fishing-rod, and this manœuvre he recommenced in every fresh place where he threw out his line. To my questions he answered that he did so to attract the fish (small Characini, which are often anything but timid).

Professors Bridge and Haddon (I*b*, p. 280), however, say:—

" . . . It may be urged:—(1.) That *the majority of the Ostariophyseæ are certainly not 'bottom' or 'ground' fishes* in the same sense as, for example, are the Pleuronectidæ. . . . Moreover, there are many facts which tend to prove that *whenever any Ostariophyseæ assume a strictly 'ground' habit*, as . . . Glyptosternum, Exostoma, Euclyptosternum, Amblyceps, &c., in the Siluridæ, *the air-bladder necessarily* becomes useles for hydrostatic purposes, *and invariably undergoes more or less degeneration.* . . ." On the European *Silurus glanis* Lilljeborg [2] says: "When grown up, it prefers deep waters with muddy bottom, and remains all the day long concealed beneath prominent banks, roots of trees, sunken sticks, big stones *a.s.f.* When younger, it is found at smaller depths but particularly in

[1] Poey, F.: Memorias sobre la historia natural de la isla de Cuba, T. II., 1856–58, pp. 97 and 98. Quoted in my *Lydorganer*, p. 155.

[2] Lilljeborg, W.: *Sveriges och Norges Fiskar*, T. III., Upsala, 1891, p. 371. (The passage is translated by me.)

places with muddy bottom and furnished with vegetation and hiding-places. It generally keeps to the bottom and is slow and dull in its movements, whereas during stormy and rough weather it proves more lively and then it is also moving about." Bloch [1] and Cuvier et Valenciennes (XV., T. XIV. pp. 348–349) state essentially the same habits for this species.

Day, who in India has seen lots of Siluroids, and who is generally acknowledged to be a good observer of living animals, says [2] on Siluroids in general: "These fishes delight in muddy localities." In another paper, also found among the "References" of Professors Bridge and Haddon, the same author [3] (p. 719) has shown that the freshwater Siluroids of India abound in muddy rivers but are more or less rare when the water is clearer and the bed more stony. Thus, with regard to the Siluroidæ in general, Day has proved the nature of the bottom [4] to be of great consequence to these animals. I should think, that if the Siluroidæ were not ground fishes, the nature of the bottom would be of little or no consequence to them. And it is not difficult to understand, that to these fishes the nature of the bottom is of great consequence: where the bottom is muddy and accordingly smooth they have no difficulty in finding their food by means of the feelers, while these cannot easily pass over the bottom where it is stony and consequently rough. The opinion which Day himself entertains on this subject, is still more conspicuous in another place: [5] "Living, as they [the Siluroidæ in general] do, the life of ground feeders, and mostly restricted to muddy localities . . ." I, too, have seen many Siluroids, especially in Rio Paraguay. Perhaps what I have

[1] Bloch, M.E., "*Oeconomische Naturgeschichte der Fische Deutschlands*," T. I., Berlin, 1782, p. 245.

[2] *Journ. Linn. Soc.*, XV. London, 1881, p. 38.

[3] XVIII: Day, Fr., "On the Freshwater Siluroids of India and Burmah," *Proceed. Zool. Soc. London*, 1871, pp. 703–721.

[4] As no mud is deposited where the current is rapid, and a stony bottom only exists where the current is rapid or the water very low, the conclusion might perhaps be drawn from the statements of Day that the Siluroids only live in stagnant waters or in rivers where the current is slow. I must therefore point out that this is not the case, at least not in Rio Paraguay, for in this river, where Siluroids are abundant, the current is not slow : the bottom is constantly changing, and during a great inundation even close to the banks of the river bed the current was so rapid, that in some places a *small* steamboat found some difficulty in going up the river.

[5] Day, Fr., *Fishes of India*, 1878, p. xv.

observed of the habits of these fishes, may serve to elucidate this question; I therefore take the liberty to translate what I have written on this matter, 10 years ago (II*b*, p. 7, the footnote):—

"In the stomach of Platystoma and Pseudaroides are found fishes and, to a less degree, vegetable substance. Doras, on the contrary, is a veritable 'bottom-scraper'; in its stomach are found fishes of different size, snails (Ampullaria), bivalves (Unio), particles of grass, leaves, pot-plants and other refuse, nay, even rags and match-boxes of pasteboard."

And (*ibid.*, p. 102 *sequ.*) I expressed myself nearly as follows:— *On the circumstances under which the Siluroidæ produce sounds.* —The sounds produced by the Siluroidæ and by the Characini, of course differ in intensity according to the different species and the size of the specimens. Among the Fishes I have heard, Doras emits the strongest sounds; a specimen of the length of 70 ctm. is still distinctly heard at a distance of 100 feet, by day and in the air, that is: when the animal is on shore. How far the sound may be heard in the water, I have not learned. That there the sound may be heard at a much greater distance, is evident,[1] the water being a far better conductor of sound than the air. As to the time at which the Fishes spontaneously emit sounds, you will not unfrequently hear them, when you bend your head over the river-brink, where it is steep, or still better, when you are on the water in a boat. On a calm evening or night, or on quiet days when the sky is overcast, you may hear a growling sound arise on all sides around you—for Rio Paraguay is very rich in fishes. No wonder that the sound is dull, for a sound always grows fainter when it is transmitted from one medium to another.[2] The sound is most powerful and most intense, when on such an evening you are in the hold of a sailing

[1] The more so, as the intensity of the sound is not dependent on the density of the air in which the sound is heard, but on the density of the air in which it is emitted. From this we may conclude that the intensity of the sound produced must be greater in the water, where (it is so, at least in several places in Rio Paraguay, *f.i.* near the mouth of Riacho del Oro) the air in the air-bladder can be under a pressure of about 1½ atmospheres : 16 feet of water.—(This note has been added on this occasion.)

[2] And this is particularly the case with regard to such sound-waves, which strike the surface of the water at an angle, that differs somewhat from the perpendicular line.

vessel, which is anchored up or slowly gliding through the water before a soft breeze. Then, the intensity of the sound is quite surprising. Often—before I knew what it was—I have got out of my berth and have walked on deck to listen to these strange sounds, but then it appeared to me, as if I could hear nothing at all; such was the difference. But for the very reason that, during a voyage which lasted for some time, I do not remember ever having heard these sounds except in quiet weather, I dare presume, that the fishes do not spontaneously emit any sounds when the water is agitated; for while it is probable that the ear cannot catch the sound when it is transmitted to the air from water with an undulating surface, this will be of no moment when you find yourself in the hold of a vessel, that is to say: immersed in the water.

When animals produce *spontaneous* sounds, it is done in order to summon other specimens of the same species to approach. This is so general a rule that it might be taken for granted with regard to the Siluroidæ; but the present case may be adduced as a proof of its correctness. For those sounds, spontaneously emitted by the fishes themselves—under no influence from without—are loudest, and the number of the animals joining in the chorus is greatest at fixed seasons, *f.i.* in February and March, but at that very time I have found in several specimens of the above-mentioned Siluroids the ovaries bulging with eggs, and I have met with tender young ones. But there is another fact so obvious that I hardly need point it out here: the Siluroidæ produce a much stronger sound than do the Characini, and most intense among all is the sound emitted by Doras. But the Siluroidæ are, more or less, ground fishes, for such they are proved to be, not only by what I have mentioned above about their food, but by their barbels, and their small,[1] dull, almost pigmentless eyes. And those furnished with

[1] For instance: the eye of *Pseudaroides clarias*, the total length of the Fish being 39 ctm., has a diametrical length of 9, 5 mm.; the eye of Doras, whose total length was 69 ctm., has a diametrical length of 6, 5 mm. (The eye of *Tinca vulgaris*, whose eyes are small when compared with those of our other freshwater Fishes, has, according to Kröyer, a diameter of 10, 9 mm., the total length of the Fish being 34 ctm.) As a curiosity I may here add that in a Pseudaroides I once found 3 small bony scutes in the cornea. Day (*Fishes of India*, p. 438) also mentions that the Siluroidæ in general have but small eyes.

the smallest eyes, almost entirely devoid of pigment, are the Doras, which emit the loudest sounds, and with regard to which it is a well-known fact in the Argentine republic, that when you go out angling for species of this genus, you require a long line reaching to the bottom of the river. Further, if we take into consideration that the water of Rio Paraguay and Rio Parana (baja) is so filled with floating particles of clay, that it is of a dingy, yellowish colour, which is anything but pleasing to the eye, to such a degree that when you thrust your arm into the water to the elbow, you can distinguish your hand no more. It is evident, then, that, in these fishes, the two sexes are guided much less by the eye than by the ear in finding each other.—So much as to the spontaneous sounds which the animal emits of its own accord. But when it has been caught and lies bleeding and struggling on the ground, the sounds produced by the air-bladder, cannot be designated as voluntary sounds but must rather be called convulsive; the Fish, in its agony making the most desperate and purposeless efforts to extricate itself from the danger, strains every vigorous muscle. No wonder, therefore, that some fishes, as *f.i.* the Siluroids in question, when captured, readily emit sounds by means of their air-bladder, while others do so much less frequently, and others again so rarely emit any sound that it is rather difficult to establish the fact that they produce any sound at all. For that depends on their general character and on the strength of the muscles which make the air-bladder produce sounds. No wonder, therefore, that we have but *comparatively* few records of sound-producing fishes, for we know but very little of the biology of aquatic animals.

With regard to the sounds, which the Siluroidæ produce by means of the foremost ray of their pectoral fins and the great ray of their dorsal fin, that is another matter. To begin with, I have pointed out the impossibility of distinguishing between the two functions of these rays, that of a weapon and that of an organ of sound. When the fish is caught, it generally produces sounds by means of the pectoral fins, moving them backwards and forwards. The dorsal fin, on the contrary, is but very rarely moved but is kept quite erect. This may be easily accounted for. If you seize the fish from behind,[1] it will

[1] If you seize the Fish in front, it cannot strike and makes no effort to do

instantly stop the movement of the pectoral fins and bend its body backwards with a vigorous stroke, while endeavouring to hit your hand.[1] What it aims at, when caught, by moving its pectoral fins, while producing sounds, is to change its weapon from one position of defence to another, always ready for an attack; in order to do so, to keep the weapon ready for a stroke, it is obliged, during its movements, to keep the strong ray as much as possible in the exact position, in which it is fixed. Vertically, on the contrary, these fishes can curve their body but very slightly; the strong ray of the dorsal fin, therefore, very seldom changes its position but is kept erect as a passive weapon, ready to wound the aggressor by his own movements. Therefore, we must also suppose that the sounds produced by the rays may have the secondary intention to scare the assailants, and even under these conditions the sounds emitted by the air-bladder may be considered as voluntary, as they serve to intensify the effect of the sounds produced by the strong rays. And that this is the case, is confirmed by the fact that both sounds, at least as long as the fish is in possession of its full vigour, are, as a rule, contemporary, so that it is no easy matter to distinguish the different sounds, as long as you are inexperienced. In other fishes, such as Diodon and Tetrodon, the sounds emitted may also be considered a threat, as appears also from what Pappe[2] says about *Tetrodon Honkenyi*, Bl.:—

> "As soon as it is taken out of the water, it becomes inflated to a considerable extent, utters a particular sound resembling a grunt, and by its sparkling eyes, which then look truly terrific, betrays extreme ferocity."

Several authors have suggested, that the sound emitted by Gymnodontes, when captured—for also in the order of the Plectognathi, many species are known as sound-producing—is

so; like all other fishes, it only tries to make itself free by means of violent movements. In this case the movements and sounds produced by the pectoral fins generally continue.

[1] I have been slightly wounded a few times by *Pseudaroides clarias*, which makes the most vivacious movements; the wound was healed without any difficulty and without any appreciable inflammation.

[2] Pappe, L.: *Synopsis of the edible Fishes at the Cape of Good Hope*, Capetown, 1853, p. 8.

effected by the expulsion of air from their subcutaneous sac[1] when inflated. This suggestion is not very judicious. Why do these fishes inflate their bodies with air? Whoever has dissected a Diodon furnished with long spines, *f.i.* a *D. hystrix*, or whoever has seen specimens of this species, dead or alive, inflated and uninflated, cannot have failed, I presume, to notice that the spines of the inflated animal are bristling on all sides like the quills of the Hedgehog, while they are turned backwards when the fish is uninflated. Hence this sac proves to be an organ of defence, of which fact Cuvier was already aware, and in the species furnished with long spines a most precious one too, and according to what I am immediately going to state, the fish is well aware of this fact. Even if the fishes be so stupid, as, in our intellectual arrogance, we generally think, I, at all events, cannot consider them to be stupid enough to expel some air and, so doing, to weaken this important means of defence, to gain another, at any rate most doubtful end—that of scaring the enemy by emitting a sound. But in literature, there also exists a most important testimony against this suggestion.

Mitchell (*loc. cit.*, p. 473) says as follows:—

". . . and the fish [*Tetrodon turgidus*] will bear to be kicked about without discharging it [the air]. I have seen them stamped upon, and still retain their charge of air. I have known them to bounce from the surface of a rock, against which they have been thrown, as turgid as ever. And it is a piece of sport, common enough among fishermen, to burst them between two stones, where the air is let loose with a noise almost equal to the report of a pistol."

Lastly, I take the liberty to urge—perhaps the most important argument against this suggestion—that in *Diodon hystrix*, the only species I have dissected (dead) of this genus, the air-bladder is undoubtedly a sound-producing organ,[2] being

[1] The subcutaneous sac is not connected with the œsophagus but opens as well in Diodon as in Tetrodon, behind in the pharynx. See my paper "Om Oppustningssækken hos Tetrodon," (*Naturhistorisk Tidsskrift*, 3 R. T. XIII. Kjöbenhavn, 1883, pp. 379–396).—Authors, who say that the air-bladder in Plectognathi opens into the alimentary canal, have examined the subcutaneous sac and not the air-bladder, which in these fishes is destitute of a pneumatic duct.

[2] At least in *Diodon rivularis* this is the case, according to the description given by Delaroche (XIV. p. 195): the air-bladder is furnished with a pair of extrinsic muscles in the same manner as in *D. hystrix*, and, moreover, with an intrinsic muscle.

deeply bilobed in front and provided with a cap-like prominence behind—the wall of which differs from the rest of the air-bladder—and an interior, narrow, prominent perpendicular membrane all round the border of the cap; the air-bladder is also provided with a pair of extrinsic muscles. I must also suppose the air-bladder to be a sound-producing organ in *Tetrodon fahaka*, the only species I have dissected of that genus, as well as in *Balistes vetula, Monacanthus pardalis, Triacanthus brevirostris* and *T. biaculeatus, Ostracion trigonus* and *O. triqueter*.[1] While thus, with regard to a smaller number of fishes, I am able to point out which is their intention in producing sounds when captured, I suppose that, with regard to many fishes, it will be very difficult to indicate any reason for their production of sounds, when captured, but partly, at least, they must be supposed to be caused by purposeless, convulsive movements. According to what I have said above as to the use of the pectoral fins[2] of the Siluroidæ in question, I must consider their becoming the prey of other fishes as nearly impossible. Pseudaroides and small specimens of Platystoma, as well as a species of Pimelodus, which seems less frequent, I have found, however, in the stomach of large fishes, both in Doras and in Platystoma, but never, as far as I remember, have I seen any Doras in the stomach of another fish. This fact, too, is easily accounted for: Pseudaroides betrays great vivacity in its movements, and continually changes the position of its pectoral fins; with some dexterity the assailant may not only gradually succeed in gaping over (the edge of) the spine-like rays, when these rays are moved backwards, but—what is more important—the rays cannot be so firmly fixed in this genus (and still less in Platystoma); thus when the fish gets tired with struggling, the aggressor will find no great difficulty in bending them back-

[1] Also in *O. cubicus*, according to the description given by Cuvier, and in two other species of this genus, according to the descriptions given by Poey. See my book (II*b*, pp. 134–146).

[2] Lütken, C. F.: "A Brazilian told Dr. Lund that once he saw a small 'Pacu' [*Auchenipterus lacustris*, Rhdt.] thrusting its pectoral spine into the body of a 'Trahira' (Macrodon) much larger than itself; the Trahira bounded on shore out of the water, and was captured along with the 'Pacu,' which was still attached to it."—"Velhas Flodens Fiske, et Bidrag til Brasiliens Ichthyologi" (*Danske Vidensk. Selsk. Skr.*, 5 R. Bd. XII. 2, Kjöbenhavn, 1875, p. 148).

wards. In the more sluggish Doras, on the contrary, the spine-like rays of the pectoral fins are always nearly fixed and will not easily change position when the fish is dead.[1] Only fancy with what an enormous mouth an animal must be furnished in order to succeed in swallowing a fish, that with a length of *f. i.* 69 ctm., is proportionally thick, and on whose body there exist three spine-like rays of a length of 13 ctm., bristling out to either side. I therefore presume that no other animals, except those which, like the jaguar, the otter, the caiman and the piraya, are able to bite or tear their prey to pieces, will succeed in seizing this fish.

Though I am by no means of opinion, that the fishes known to us as sound-producing, are more than a small fraction of those gifted with this faculty, I do not consider myself too rash in presuming that those forms with which we are acquainted, most decidedly go to show that this faculty particularly exists in fishes, which, with regard to their habits, must be classed among two groups: Fishes living in fresh water, where the sight plays a less prominent part, and fishes living in shoals.

If, moreover, we bear in mind what I urged before, that it is in the spawning season that the Siluroidæ most frequently produce sounds of their own accord, and that Holbrook (*loc. cit.*) has made the same experience with regard to *Pogonias chromis* as well as Dufossé (V*b*, pp. 14 and 15) with regard to *Sciæna aquila*, I am of opinion that my readers will agree with me when I set forth the following opinion:—*The sounds which fishes produce by means of their air-bladder have the biological importance, generally spoken, to serve those of the same species as a means of communication, particularly in the requirements of sexual life*, and in certain species to scare away an assailant.

What I have here stated of our knowledge as to the habits of the Siluroidæ, bears, I think, further witness, too, to the sharp hearing of these fishes. I cannot imagine that anybody would deny the correctness of my suggestion that the voluntary sounds which the fish produces by means of the air-bladder, are emitted as an audible signal to other fishes of the same species. But this would be all in vain, if those, for whose sake the sounds were emitted, were not sharp enough of hearing to catch these

[1] I do not here pay any regard to specimens preserved in spirits.

sounds. And is not the fact, that the sounds emitted by sound-producing Siluroids are stronger than those emitted by sound-producing Characini which inhabit the same waters, in accordance with this suggestion and with the different habits of these animals, the Siluroidæ living, more or less, near the bottom, the Characini comparatively near the surface of the water?

2. *Is the Transmission of Sound from water to the air-bladder of a Fish accompanied by a considerable loss of intensity?* Professors Bridge and Haddon answer this question in the affirmative (*Ib*, p. 273), referring (p. 272) to the experiments of Colladon and Sturm. Totally apart from what I myself have heard with regard to fishes, I fail to see that the famous experiments made by Colladon[1] at the Lake of Geneva prove that this question has to be answered in the negative. Colladon (p. 334) says—it is true, that when the sound of his bell, struck under the water, was transmitted through the water, it was possible to him to catch the sound at a distance of 2009 metres by immersing his head into the water, while he could not catch the sound at a distance of 200 m. when approaching his ear to the surface of the water or even when bringing it "en contact immédiat avec cette surface." But the author expressly states the reason of this phenomenon to be, that the sound-waves in this case strike the water at a very acute angle, and are therefore rejected into the water without being communicated to the air—*i.e.*, the general law as to the transmission of motions *f. i.* of light. That the intensity of the sound is diminished, and even considerably, when passing from the water to the *atmosphere*, I must consider as being beyond doubt, from what I have heard of the sounds produced by the fishes in the water. But at the same time it is undoubtedly the result of the experiments of Colladon that sound-waves will be but very little diminished in strength, if they be so at all, when they pass from the water to a small space filled with air, and surrounded on all sides by water. Even if it is superfluous, I must bring to mind, that the instrument which Colladon made use of in his experiments in order to observe the transmission of sound in water, consisted of a metallic tube,

[1] Colladon et C. Sturm, "Mémoire sur la compression des liquides" (*Mém. prés. p. div. sav. à l'Acad. d. Sci.—Sci. Math. et Phys.*, T. V., Paris, 1838, pp. 267–347).

the narrow mouth of which rose above the surface of the water, and which widened at the lower end into a small metallic box. One side of this box, which was flat and made of a very thin metallic sheet, faced the bell, which was lowered into the water, and by means of which he was producing sounds. Before he had quite succeeded in rendering his instrument perfect, he tells (p. 336) that when the bell was struck at a distance of more than 2000 m. he very distinctly heard the sound emerging from the mouth of the tube, and this sound was strong enough to render each stroke audible at a distance of more than 2 m. from the mouth of the tube. And when he had succeeded in rendering his instrument perfect, he states that the sound produced by a stroke of the bell, heard by means of his instrument at a distance of 14,000 m., appeared to him as intense as the same sound, heard at a distance of 200 m. when he had simply immersed his head into the water. And he expressly says (p. 336, the footnote) that he heard nothing at all, if the instrument were not closed and completely filled with air. These statements appear to me clearly to prove that the sound is hardly weakened when passing from the water to a small space filled with air, and surrounded on all sides by water and separated from it only by a membrane, which, like the metallic sheet of Colladon's box, or the wall of the air-bladder, is well adapted, to be thrown into sound vibrations.

3. A third objection against the theory of Weber is urged (I*b*, p. 273) that in many Siluroidæ the walls of the air-bladder must be too thick to admit of their vibrating synchronously with rapidly recurring sound-waves. But with regard to this point it must be borne in mind that the walls of the air-bladder *can* be thrown into such vibrations (when the air-bladder is sound-producing), a fact which is fully proved by the investigations of Dufossé and Moreau as well as by my own—and that the air-bladder becomes a better organ of sound exactly in proportion to its walls being thicker (or more elastic). But if so, it would be impossible to deny that the walls of the air-bladder may be thrown into vibration, when sound-waves strike them from without. The only objection—or rather modification—in a certain respect, which may arise out of this ground against Weber's theory, such as he himself has propounded it, is, as far

as I can see, the one which I have suggested ten years ago and which I am soon going to enter upon.

4. *On the Conditions for the Movement of the Weberian Ossicles.*—An objection, and even an insuperable one, has been sought in the suggestion that the Weberian mechanism were not able to transmit sound-vibrations from the air-bladder to the ear (or, strictly speaking, to the atria sinus imparis), because the ligaments interconnecting the Weberian ossicles were supposed to be "lax," so that slight movements of the posterior of these ossicles, the malleus (tripus, Br. and Hadd.) would necessarily effect only a swelling, or a straightening, of the ligament, without being able to effect any motion of the anterior one—the stapes (scaphium, Br. and Hadd.). Professors Bridge and Haddon, who have raised this objection (*ib.*, pp. 263–265, 274–275), are of opinion that this question requires a more critical examination than has been afforded by previous writers.

I wonder if a little experimental examination would not have been of still better effect. Though I never mentioned this fact, I have, by examination of recently killed Siluroidæ and Characini, ascertained that there exists that consecutiveness of movements in the Weberian ossicles which would be requisite in order to render possible the transmission of sound waves. Whether Weber has done so, too, cannot be ascertained, but there is every probability that he did so: Weber was a conscientious investigator, and an eminent physiologist of his time. I hope I may be excused for not entering upon further explanations with regard to the Siluroidæ and the Characini; seventeen years having passed since I was in possession of recently killed specimens of these animals, I am no longer able to recollect the details. Therefore I have now examined the *Cyprinus carpio*, which is, in fact, better adapted to this examination, as the malleus is connected by means of soft tissue with the centrum of its vertebra, whereas it is developed into the form of a spring in those Siluroidæ and Characini which I have examined shortly after their death.

Experiment A.—When in a recently killed *Cyprinus carpio*, the malleus is set free from the wall of the air-bladder, and the stapes is loosened from all its connections with the skull and the vertebral column, with the exception of the connection between

the lower end of the stapes and the centrum of the first vertebra, then the stapes is more projecting laterally than when in its natural position, the ligament, which connects the different ossicles, being somewhat contracted. *For this ligament is not at all*—neither in the Cyprinoidei, nor in the Siluroidæ, nor in the Characini—*a lax ligament, as suggested by our authors*, but as I pointed out in my previous publications, a tight elastic one. From the position which the malleus occupies when left alone under these circumstances, it can hardly be moved backwards, the os suspensorium (mihi; the transverse process of the true fourth vertebra) preventing this movement.[1] When the malleus is turned forwards, by means of a needle[2] or scalpel, the incus and the stapes move as much as the malleus.

Experiment B.—When in a recently killed *C. carpio* the Weberian ossicles are exposed, without opening the abdominal cavity, *i.e.*, without touching the air-bladder, they will appear in their natural condition. Then the malleus proves to be turned less far backwards than in the previous case: it can be turned a little farther backwards by means of the needle, but not much. From its present position of rest, this ossicle can be turned more forwards than backwards. If you do not use force, the movements backwards and forwards, effected by means of the needle, are but slight. Under these conditions, the malleus does not move backwards at all, when you turn the incus (intercalarium, Br. and Hadd.) outwards (or backwards). When, on the contrary, by means of the needle, you move the malleus ever so slightly, whether backwards or forwards is all the same, both the incus and the stapes also move; and as far as I was able to distinguish (of course by means of a lens, one of small and another of rather high power) the movements of the incus as well as those of the stapes were precisely equal

[1] The same is the case in the Characini; most probably also in the Gymnotini, of which I have only examined older specimens preserved in spirits; in the Siluroidæ the case is similar; how it is brought about, I no longer remember. This family presents more difficulty, for several reasons; among others, because, in the genera which I have examined, the malleus was connected, by a short but broad ligament, with the transverse process of the (true) fourth vertebra, whether the said process be developed as an elastic spring or no.

[2] By placing the needle on the midst of the malleus and then pushing it forwards or backwards.

to those of the malleus. The slightest movements obtainable in this way, are produced by scratching on the surface of the malleus with a needle, the point of which had been curved: as soon as the point of the needle, which has caught hold of the surface of the malleus, lets go this hold, all three ossicles instantly swing backwards (or forwards), all to the same degree. It appears to me as if the movements, which they then make, are a little larger, when, in scratching, you move the malleus backwards than when you move it forwards.

Experiment C.—In order to be sure that, in spite of all precaution during the said dissection, the connection of the stapes with the skull and the vertebral column had not been injured, I also exposed the incus and the malleus, while leaving intact the thin adipose tissue, which covers the Weberian ossicles, except on the middle of the malleus and above the incus, that I might be able to study the movements of the latter. The result was exactly as in case B. I may add that the moving forwards of the Weberian ossicles is due—at any rate chiefly—to the short ligaments, by means of which the stapes is connected with the skull and the vertebral column, whereas the air-bladder and the interconnecting ligaments of the Weberian ossicles cause these ossicles to be moved backwards. As the reader will observe, the whole apparatus forms, as it were, a continual tight string, and will thus be well adapted to the transmission of sound-waves, even if these sound-waves, as is quite natural, involve much slighter movements than may be observed by the above-mentioned process.

Experiment D.—I have ascertained that the movements of the Weberian mechanism are brought about in the same way in those Characini and Siluroidæ, which I have examined as to this point in the fresh condition. The following experiments I have only made on *Cyprinus carpio*, and as it was rather difficult for one person to make these experiments, a young friend of mine. Mr August Krogh, who is a student of Zoology, has been kind enough to assist me. In a recently killed *Cyprinus carpio* I laid bare the Weberian ossicles to their whole extent; then I opened the abdominal cavity, and took out the sexual glands and the intestinal canal, with its appendages, and after having ligatured the pneumatic duct, I set free the posterior sac of the air-bladder. This organ was considerably but not abnormally distended.

One of us now encompassed with his hand the posterior sac, while the other watched the Weberian ossicles. It now appeared that when a pressure, and even the slightest possible, was exercised with the extreme phalanx of a finger on the posterior sac, a movement upwards and downwards of the Weberian mechanism became distinctly visible, provided that the pressure set in quickly and was quickly discontinued. This movement was so large that we could see it quite distinctly with our naked eyes.[1] When the anterior sac is distended by means of a pressure on the posterior one, the Weberian mechanism moves upwards. The excursions of the stapes and the anterior process of the malleus were equally large; whereas we could not distinguish any movement of the claustrum,[2] which in the Cyprinoidei (but not in the Siluroidæ known to me) forms the upper part of the interior wall of the atrium sinus imparis.

Experiment E.—I have not had any apparatus which could show so slight movements as must take place in the Weberian mechanism, when the air-bladder is influenced by sound-waves. I have succeeded, however, in getting a little nearer towards my aim. As I have mentioned before (II*b*, p. 180), you can make any air-bladder tune when distended by the air within, if you strike it softly with a steel spring of convenient (small) strength. Now, when in this manner one of us threw the anterior sac of the air-bladder into sounding vibrations, the other was able to distinguish longitudinal vibrations in the Weberian mechanism; these vibrations, however, could only be observed by means of a powerful lens, and it was not always equally easy to observe them. They are most distinctly visible at the upper edge of the stapes for several reasons, among others because the movements are here most easily distinguishable in the small quantity of serum, which is found here on account of the dissection. In another specimen, in which the air-bladder was not so much distended by the contained air, it was much more difficult to distinguish these vibrations.

[1] To compare with what I have said above, the experiment "F" found in my criticism of the theory of Bridge and Haddon.

[2] Hasse (in his second paper, quoted later on in the discussion of his theory pp. 590, 591) supposes the claustrum to share in the movement of the stapes: "Jede Bewegung des stapes *muss* demnach von einer Bewegung . . . des claustrum begleitet sein."

Professors Bridge and Haddon also object to the theory of Weber that the Weberian mechanism differs in its adaptation from the tympanic ossicles of the ear of Mammalia.

In the Reptilia and the Birds there exists, as is well known, *one* auditory ossicle, one end of which is fixed to the tympanic membrane, while the other end is inserted into the fenestra ovalis. In the Mammalia, the transmission of sound vibrations between the tympanic membrane and the inner ear is brought about by a chain of auditory ossicles, which are fixed to the wall of the tympanic cavity by means of ligaments which determine the axis of their movements, and are interconnected by *true* articulations (diarthroses). In both cases, the organs which serve to catch the sound-waves, and those, related to the transmission, are homologous.[1] It is quite natural, then, that the aim of their activity is obtained by the same process: that the sound-waves, striking the tympanic membrane, press it inwards, and that by this means the inner end of the auditory ossicle—or ossicles—is slightly pressed against the endolymph of the inner ear. I must acknowledge, however, that the objection made by Professors Bridge and Haddon might have been of some importance, if it had appeared, while Weber was still alive, for he considered the ossicles which are bearing his name, as homologous with the auditory ossicles in the Mammalian ear, and it might have been pointed out to *him* as a mark of inconsistency that, in organs which were homologous and serve the same physiological purpose, the same plan had not been followed up. But nowadays, all authors agree that this homology does not exist, and, consequently, this objection has no longer any weight.

When the sound-waves strike against the body of the fish, and the vibrations are transmitted to the air-bladder, the first, momentary, movement of the latter will consist in the contraction of the organ itself, so that *f.i.* its anterior wall is pressed backwards, and subsequently, the posterior crescentic process of the malleus (tripus, Br. and H.), which is embedded in the wall of the air-bladder, is drawn inwards and a little backwards, and by means of the tight elastic ligaments which unite it with the rest of the Weberian ossicles, this movement causes the said

[1] Or, strictly speaking, *nearly* homologous, the columella of the Birds and Reptilia being homologous with the stapes (of the Mammalia) alone.

ossicles to move backwards, so that the stapes (scaphium, Br. and H.) is removed from the atrium sinus imparis, the lateral wall of which it constitutes. By the next momentary movement of the wall of the air-bladder, its anterior wall is moved forwards: by this movement the malleus is turned forwards and the inter-ossicular ligament is slackened (or rather: rendered less tight) at the fore-end of the malleus, while, accordingly, the ligaments which unite the stapes with the rest of the wall of the atrium sinus imparis, and which had been straitened by the previous movement, now contract, so as to bring about a pressure by the stapes on the perilymph of the atrium. There is one circumstance, which will render the vibration of the wall of the air-bladder more vigorous in the place where the posterior crescentic process of the malleus is embedded in it, than in all other places, and this is, that the wall of the air-bladder is fixed, at a very short distance from the posterior process of the malleus, to the immovable parts of the vertebral column (except in the Siluroidæ, to the os suspensorium mihi); and as I have already pointed out, ten years ago, that part of the wall of the air-bladder, which lies between the posterior process of the malleus and the immovable parts of the vertebral column, is always very elastic, even in the Siluroidæ, in which, however, the rest of the air-bladder is but *very* little elastic. There is still another noteworthy circumstance. When the incus (intercalarium, Br. and H.) is connected with the centrum of the (true) second vertebra—in the Characini and the majority of the Cyprinoidei—then the distal ends of the Weberian ossicles (and the interconnecting ligaments) form a regularly curved arch, in which the different parts are the nearer to the central line of the body the more they advance in front. Hence the force with which the stapes is moved from the atrium sinus imparis is augmented, the incus acting as a pulley. But the force with which the stapes is moved is increased to a still higher degree in the Cobitini,[1] the Siluroidæ

[1] For *Misgurnus fossilis* and *Cobitis barbatula* see Weber (XVII. pp. 62 and 67; Tb. vi. Figg. 49, 50; for *Misgurnus fossilis* and *Nemachilus Strauchii* see my second paper (III. pp. 120, 122; Tb. iii., Fig. 27); also my French "Resumé" (*Ibid.*, p. 133). I do not know that more species have been examined with regard to this point. According to Baudelot, M. E.: "De la termination des pièces osseuses qui se trouvent en rapport avec les premières vertèbres chez les Cyprins, les Loches et les Silures" (*Comptes rend. de l'Acad. d. Sci.* T. LXVI. Paris, 1868,

(*i.e.*, in all I know of), and the Gymnotini.[1] In these fishes either the incus is not connected with the centrum of the vertebra, being only a small osseous nodule in the interossicular ligament, or it is completely wanting;[2] but in both cases the fore-end of the malleus reaches much farther in front, and in the Siluroidæ it even reaches as far as the stapes. Accordingly, the force with which the vibrations of the malleus are effected will—on account of its more favourable angle of traction—be all available to move the stapes from the atrium sinus imparis.[3] This circumstance is, I should think, in perfect accordance with the fact that these animals[4] are ground-fishes to a greater or less degree.

6. Bridge and Haddon say (*Ib*, p. 276): "(*e*) Even if the admission be made that the air-bladder and its ossicles are accessory to hearing, the fish would have no power of appreciating the direction of sounds conveyed to the internal ear by such means. Any cognizance of the varying directions from which sounds may come is generally believed to be due in all vertebrated animals to the differential action of the two ears, but we have already shown that no such action can possibly take place in response to impulses received through the Weberian mechanism in accordance with Weber's theory." The reason why they are of this opinion they have given on p. 268: "No differential action of the two sacculi can possibly take place, at all events so far as impulses received through the Weberian mechanism are concerned, since the only channel through which any movement initiated in the fluids of the atrial cavities by the motion of the Weberian ossicles can reach them is the median and impaired sinus endolymphaticus; hence it must follow that each sacculus will be affected by any such disturbances to an equal extent and at the same moment."

As far as I can see this is the only real objection that can be made against the theory of Weber. But I do not judge it to be

p. 330), the same is the case in the Cyprinoid genus Catostomus, while according to Professor Ramsay Wright (op. cit. below, p. 379), "the proximal end of the style-like incus contains cartilage, and projects from the second vertebra."

[1] Among these, with the Weberian ossicles in view, are investigated: *Carapus fasciatus*, *Sternarchus Brasiliensis*, *Sternopygus Marcgravii et microstomus*, by the late Professor Reinhardt (*Videnskabelige Meddelelser fra den Naturhistoriske Forening* i Kjöbenhavn, 1852, pp. 135–149), and *Carapus fasciatus* and *Sternopygus carapo* by myself (III. Tb. i. Fig. 7).

[2] That the incus, if present, should, in this case, have any functional importance, appears also to me to be beyond the range of probability.

[3] The influence exerted by the different position of the incus on the *direction* in which the force is acting, has not escaped the attention of Professors Bridge and Haddon (*Ib.*, pp. 265, 266).

[4] I must here make a reservation with regard to the Gymnotini, as I do not know the habits of these fishes.

of great importance. If this objection were absolutely valuable, no human being would be able to decide if a sound arises before or behind him, when the direction of the sound coincides with the symmetrical plane of the body; and this, however, we are able to decide. And would not this objection be just as valuable, if you presume the sound not to be transmitted to the ear through the air-bladder? Are not the fishes deprived of the means by which the higher vertebrata are able to judge the direction of the sound, viz., by turning the head (or external ears) to the right or the left? It must also be kept in mind that it is always very difficult thoroughly to understand that beings differently conditioned know how to make use of the powers with which they are endowed, especially when these powers are inferior to those bestowed on us: a rich man hardly understands that a poor man can make both ends meet; a clever shot of modern times fails to understand that pistol-shots can have excelled in their profession 200 years ago when he considers the clumsiness and unsteadiness of the pistols of that time; in our century, which may be justly called the *steel-age*, it draws from us the greatest admiration and surprise to see the sometimes remarkable works left to us by the people of the flint-age, in spite of the clumsy instruments which may have been at their disposal.

7. Again, the authors still urge one objection (*Ib*, p. 276):

> "(3.) Finally, it may be affirmed that there is an alternative view of the function of the Weberian ossicles, which is in perfect harmony with the facts of structure, and is open to none of the objections which can be reasonably urged against Weber's theory, and also, at the same time, has an important bearing on the locomotor activities of the fishes concerned."

That the theory of Hasse, if it were well founded—or rather: that the foundation of Hasse's theory, if it were correct—would hardly admit the adoption of Weber's theory, I do not fail to see. But when here, as everywhere in their work, the authors declare the theory of Hasse to be correct, I must point out in this place already, that without being aware, it is true, of their doing so, they have propounded objections to this theory which they themselves declare to be of great moment, and among which one is, in fact, very important. Even if the theory of the

authors (for it is not the theory of Professor Hasse) were correct that the function of the Weberian mechanism was to acquaint the fish, through the saccus endolymphaticus of the auditory organs, with the varying tensions of the gases contained in the air-bladder, this does by no means exclude the possibility of sound-vibrations of the air-bladder being transmitted through this mechanism to the saccus endolymphaticus. Finally, *I shall prove* further on, in my criticism of the theory of Hasse, that *they have not rejected the theory of Weber, because they have adopted that of Hasse, but, on the contrary, they have adopted, as they mean, the latter theory, because they have rejected the former one.*

In one or two places, I have alluded to a circumstance which, in my opinion, will necessitate a modification of the theory of Weber, with regard to those fishes, in which the air-bladder is a sound-producing organ. But I must here expressly point out that in those of the Ostariophyseæ, in which we know the air-bladder to have this function, the malleus is an elastic spring. I must also point out that among the Weberian ossicles, I count the os suspensorium (mihi) in the Cyprinoidei, the Characini and Gymnotini, as well as the big elastic spring with its distal circular plate, on whose anterior face the muscles are attached, the contraction of which makes the air-bladder sound: in the genera Doras, Synodontis, Malapterurus, Euanemus, and in the genera which I do not know—Rhinodoras, Oxydoras, Auchenipterus, Pangasius (and perhaps Asteriophysis). The modification which I judge to be necessary, I have already suggested 10 years ago (II*b*, pp. 99–102), and I now take the liberty to translate this passage of my paper, with a few alterations, due to a few unimportant mistakes I then made in this connection.

" *The importance of the Weberian ossicles in the above-mentioned genera of the Siluroidæ and Characini, as to the production of sound,* may be of a two-fold nature. Where, as in Doras, muscles are inserted into one of these ossicles, this one actively sets the rest[1] of the wall of the air-bladder in motion, and consequently brings about and contributes to the production of sound—in Doras the Weberian ossicles are even capable, as I have said above,[2] of producing sound

[1] The (greatest part of the) distal circular plate of the muscular spring being an ossification of the wall of the air-bladder.

[2] See this memoir, p. 123 of this volume of the *Journal*.

independently, of their own accord, when the whole unossified part of the air-bladder is removed. In that case, it is obvious that the number of vibrations of the rest of the wall of the air-bladder must be regulated by those among the Weberian ossicles, which are springs. But even where no muscles are inserted into any of these ossicles (in Platystoma, Pseudaroides and Pygocentrus), yet, when once thrown into vibration, they will produce more vigorous, more energetic vibrations than could be effected by the membranaceous wall of the air-bladder alone. Even in that respect, it is significant that there is but a very short distance between the hinder end of the malleus and the point where the air-bladder is connected with immovable parts of the skeleton, and that the part of the wall of the air-bladder, which lies between the malleus and these skeletal parts, is ever very elastic, even in the Siluroidæ. Weber was the first to describe (in extenso) the ossicles bearing his name, in the Cyprinoidii and *Silurus glanis*, in his justly celebrated work, *De Aure et Auditu Animalium Aquatilium*, and he pointed out that they serve to connect part of the ear with the air-bladder. The latter organ he considered to be, in these fishes, a means of intensifying sounds striking the body of the fish, while he supposed the ossicles instrumental in transmission of sounds to the ear; thus he attributed to them the same function as that of the tympanic ossicles in the Mammalian ear, and unfortunately applied to them the same names. At that time, this explanation was natural enough. But, at least with regard to the here-mentioned Siluroidæ and Characini, I can only adopt his suggestions with modifications. Firstly: it is open to no doubt that by this means is obtained an elastic and yet solid connection with the skull, which is the most solid part of the body of the fishes, because there exists a proportional, even if not symmetrically proportional, relation between the solidity of the connection between the skull and the anterior end of the chain formed by the Weberian ossicles, on one side, and the strength of the wall of the air-bladder, and that of the muscles which make the air-bladder sound on the other side. Secondly: it is also quite clear that the air-bladder, being in these fishes an organ capable, by itself, of producing tones of a certain height, is not equally able to intensify all sorts of sounds, but will be best adapted to intensify such sounds whose tones are of the same pitch and timbre as those produced by itself or by another similarly-tuned organ. In other words: the fish is endowed with a sharper hearing for sounds, emitted by (the air-bladder in) other specimens of the same species, so that fishes of the same species are able to hear each other at a greater distance than other sounds of the same intensity. And the same rule will apply also to other fishes, whose air-bladder is a sound-producing organ, even if we must suppose that it will not be the case to the same extent as when the air-bladder is connected with the ear or placed against the skull."

But even if in future that opinion of mine should be rejected, that the Weberian ossicles (if the malleus at least is a spring)

serve to determine the pitch of the tones produced by the air-bladder, I think I am entitled to consider the following results of my investigations as incontestable facts:—

1. *The wall of the air-bladder is capable of vibrating synchronously with rapidly recurring sound-waves.*

2. *The malleus is thrown into vibrations when the wall of the air-bladder is vibrating* (the posterior process of the malleus being embedded in the wall of the air-bladder).

3. *All movements, also vibrations, of the malleus are transmitted,* by means of the tightly-elastic interossicular ligament, *to the rest of the Weberian ossicles, and in this way to the contents of the atrium sinus imparis.*

4. *The tones produced by the air-bladder can be transmitted to the water without losing much*[1] in strength, if anything whatever.

But if so, sound-waves, striking the body of the fish from without, must be transmitted to the air-bladder, by which process the walls and the gaseous contents of this organ are thrown into vibrations, which are transmitted through the malleus, the tightly-elastic interossicular ligament and the rest of the Weberian ossicles to the contents of the atrium sinus imparis, and in this way to the saccus endolymphaticus of the auditory[2] organs.

This being granted, I have *proved*—

1. *That the theory of Weber is correct.*

2. That I was right when I said above, that if Professors Bridge and Haddon had made themselves acquainted with the contents of my paper "Om Lydorganer hos Fiske," the whole physiological section of their work would have presented an aspect quite different from that which it now wears.

[1] This is not the result of an inference. I have heard it. The sounds which I heard when in the hold of the vessel, were not remarkably weaker than those which afterwards I heard when stooping over the fish or the naked air-bladder. In the first case, however, the sounds of the air-bladder had been transmitted, not only to the water, but from here also to the side of the vessel, and from there again to the air inside the vessel.

[2] For Professor Hasse is the only author who contests that impressions passing through the Weberian ossicles to the contents of the atrium sinus imparis go to the ear. Whether he is justified in doing so, I am going to show further on.

(*To be concluded in the July Number.*)

ON M. DUBOIS' DESCRIPTION OF REMAINS RECENTLY FOUND IN JAVA, NAMED BY HIM *PITHECANTHROPUS ERECTUS*. WITH REMARKS ON SO-CALLED TRANSITIONAL FORMS BETWEEN APES AND MAN. By Professor Sir WILLIAM TURNER, F.R.S.

(Communicated to the Royal Society of Edinburgh, Feb. 4, 1895.)

SINCE the time when naturalists were led, by the publication of Charles Darwin's far-famed work on the *Origin of Species by Natural Selection*, to consider that Man might have been derived through a process of evolution from lower forms of animal life, attention has repeatedly been called to remains, more or less fossilised, which were thought to be transitional forms between the lower animals and Man.

One of the most remarkable specimens studied from this point of view was the well-known Neanderthal skull, discovered in 1857, along with some bones of the limbs and ribs, in a limestone cave in the Neander Valley; the characters of which, from the date of its description by Drs Fuhlrott and Schaaffhausen, have been made the subject of much discussion. Unfortunately, it consisted only of the calvaria or skull-cap, which was characterised by the great prominence of the glabella and supra-orbital ridges, the flattening of the vertex, the slope upwards and forwards of the occipital squama from the protuberance of that bone, and the long, straight squamosal suture, in all of which it approximated to the configuration of the crania of Anthropoid Apes.

On the other hand, its estimated capacity of 1230 cubic centimetres and its glabello-occipital length of 200 mm. much exceeded the corresponding measurements in anthropoid apes, and approximated it to many aboriginal Australian crania: whilst, in its breadth of 144 mm., it considerably exceeded the transverse diameter of the cranium of the Australian savage. Its length-breadth index is 72. The peculiarities of its form excited much attention, and by some observers it was regarded as transitional between man and apes, and Professor King of Galway designated it *Homo Neanderthalensis*. Professor

Huxley made a careful analysis of its characters in *Man's Place in Nature*,[1] and whilst speaking of it as the most pithecoid of human crania up to that time discovered, he showed its affinities to the skulls of some of the Australian aborigines, which are flattened on the vertex, and to crania belonging to the people of Denmark during the Stone period. He regarded it as a human skull forming the lowest term of a series leading gradually upwards to the best developed human crania, and stated that the Neanderthal man was in no sense intermediate between Man and Apes.

In a paper which I read to the Royal Society of Edinburgh thirty-one years ago,[2] I compared the Neanderthal skull with a number of specimens both of savage and British crania in the Anatomical Museum of the University, and analysed their respective configurations. I showed that the Neanderthal characters are closely paralleled both in skulls of existing savage races, and even in occasional specimens of modern European crania; and that the large transverse parietal diameter compensated for the brain space lost by the retreating forehead and flattened occiput. Shortly after the publication of this paper, Dr—now Sir Arthur—Mitchell presented me with a calvaria found in Aberdeen, whilst digging the foundations of Gordon's Hospital, which is built on the site of the Blackfriars Monastery with which a burial-ground had been connected. This specimen confirmed, in a very striking manner, the demonstration which I had previously given.[3] The conclusion above arrived at is now so generally accepted, that anthropologists not unfrequently refer to specimens of the crania of both savage and civilised races, which they are examining, as possessing Neanderthaloid characters.

Subsequent to the discovery of the Neanderthal skull, other crania have been obtained which exhibit approximately similar characters.

Two of the most remarkable of these were procured along with other bones of the skeleton, in 1886, in a terrace at the

[1] London, 1863. Also supplementary paper in *Nat. Hist. Rev.*, July 1864.

[2] Abstract in *Proc. Roy. Soc.*, Edinburgh, January 18, 1864, and *in extenso* in *Quart. Jour. of Sc.*, April 1864.

[3] The calvaria is described and figured in the *Quart. Jour. of Sc.*, October 1864.

mouth of a cave at Spy, in the province of Namur, Belgium, and have been described by MM. Fraipont and Lohest,[1] who regard them as belonging to the same race as the man of the Neander Valley. Associated with these skeletons were bones of existing mammals, and of the extinct *Rhinoceros tichorinus* and mammoth, also examples of worked flints.[2] From an examination of the anatomical characters of all the human remains, they came to the conclusion that whilst the men of Spy had possessed a number of pithecoid characters to a greater extent than in any other human race, yet that they still appeared to be human, and that between them and an undoubted anthropoid Ape there was an abyss; though the interval was not quite so great as that between the men of Spy and the fossil Dryopithecus of the Middle Miocene period.

In their examination of the bones of the lower limb of the men of Spy, MM. Fraipont and Lohest attached considerable importance to the form and extent of the antero-posterior curvature of the condyles of the femur, and to modifications in the curvatures of the articular surfaces of the head of the tibia, so as to make them conform to the large articular surfaces of the femoral condyles. They considered that with such an extent of curvature backwards of the femoral condyles, the erect human position would not have been possible, and that the trunk had been projected forwards. They are inclined to think that the attitude of these men, when standing, partook more of that of anthropoid apes, and was therefore more pithecoid than human.

Prior to the publication of MM. Fraipont and Lohest's interesting memoir, Dr Collignon had called attention,[3] in his description of the human skeletons[4] found in 1869 at Bollwiller, in the Department of the Upper Rhine, to the backward slope

[1] *Recherches ethnographiques sur les ossements humains*, &c. Gand, 1887.

[2] The French and Belgian anthropologists consider these flints to belong to the epoch which they call "moustérienne."

[3] *Revue d'Anthropologie*, 1880, vol. iii. pp. 406, 412.

[4] Two of the adult crania were dolichocephalic, but a third had a length-breadth index 79.45. In the skull of an old man the supra-orbital projections were well marked, but not especially projecting; in that of a young man they were moderate, in a woman scarcely noticeable. The basi-bregmatic height in these specimens was 130·8, 132·8, 125 (?).

(retroversion) of the head of the tibia, which gave the articular surface an oblique direction from above downwards, and from before backwards. He regarded it as a character akin to that found in the gorilla, associated with demi-flexion of the leg, and rendering the vertical attitude difficult, so that the body was less erect during progression than in existing men. The skeletons found at Bolwiller were embedded in a deposit, which is held to have been formed towards the end of the Quaternary period, and they were regarded as contemporaneous with the fragment of a skull obtained by M. Faudet in 1865, along with the molar tooth of *Elephas primigenius*, at Eguisheim, near Colmar, in the Rhine Valley.

In an appreciative review [1] of MM. Fraipont and Lohest's memoir, Dr Collignon expressed the opinion that the characters of the head of the tibia, which he had described in the Bollwiller skeletons, existed in a higher degree in the tibiæ of the men of Spy. In the following year M. Fraipont published an account [2] of a fresh examination of the tibiæ obtained at Spy, and corroborated Dr Collignon's opinion. He stated that the incurvation of the head upon the body of the tibia was very accentuated in these skeletons, and he considers that he is, as a result of this additional inquiry, still more justified in concluding that the men of Spy had an attitude less vertical than existing man, and that Man has acquired a more erect position since the Quaternary period.

In an elaborate memoir on the skeleton of a man in middle life, referred to the Quaternary period, which was exposed in October 1888, along with flint flakes and worked portions of reindeers' bones and horns, at Reymondeu, in the commune of Chancelade, in the Dordogne, Professor Testut described [3] a broken tibia, the upper end of which had the same backward direction as in the skeletons from Bollwiller and Spy. Like MM. Collignon and Fraipont, he regarded it as an ape-like character, indicating that in the standing position the knees projected more prominently forwards than in existing races. The skull was dolichocephalic, the length-breadth index being

[1] *Revue d'Anthropologie*, 1887, 3rd series, vol. ii. p. 742.

[2] *Ibid.*, March 1888, vol. iii. p. 145.

[3] *Bulletin de la Soc. d'Anthropologie de Lyon*, t. viii., 1889. Lyon, 1889.

72. The supra-orbital ridges were feeble, the basi-bregmatic diameter was 150 mm., the length was 190 mm., and the greatest breadth 139 mm. The cranial capacity, taken by Broca's method, was 1730 c.c., which is greatly in excess of the mean of modern European men.

In arriving at the conclusion as to the signification of the form and direction of the femoral condyles, and the superior articular end of the tibia, these observers had not sufficiently taken into consideration the influence which position or attitude would exercise in modifying the bones of the limbs, and the effects which would be produced by occupation, habit, and muscular action on the bones, when in the plastic stage of growth. In the memoir which I published in 1886 on Human Skeletons, in the Reports of H.M.S. *Challenger*,[1] I called attention to the squatting attitude assumed by so many savage races, as a factor to be considered in determining the shape of the pelvis and the curvature of the lumbar spine. I also pointed out the influence which might be exercised on the form and extent of the areas for muscular attachment on the scapula, in those races of men who are in the habit of climbing trees in search of food, or for other objects.

The influence of the squatting posture in modifying the form of the external condylar surface of the tibia, and in extending the articular areas of the tibio-astragalar joint in savage races, has now been worked out in detail by Professor Arthur Thomson, of Oxford.[2] Professor Manouvrier published in the following year an elaborate paper on retroversion of the head of the tibia, and on the attitude of man in the Quaternary period.[3] He examined several hundred tibiæ of neolithic men, modern Parisians and savage races, and arrived at the conclusion that, in a notable proportion of these, tibiæ occurred in which the head was as strongly inclined backwards as in the men of Spy, and in some instances, as in the tibiæ of the Indians of Cali-

[1] Zoology, Challenger Expedition, part xlvii., 1886, pp. 58, 77, 88. See also my Lecture on Variability in the Skeleton in different Races of Men, in *Journ. of Anat. and Phys.*, April 1887, p. 473, vol. xxi.

[2] *Journ. of Anat. and Phys.*, July 1889, vol. xxiii. p. 616, and additional paper in the same *Journal*, Jan. 1890.

[3] *Mémoires de la Société d'Anthropologie de Paris*, 2nd series, t. iv., 1890.

fornia, even more so; and yet these people assume, without a shadow of doubt, a vertical attitude when standing.

Still more recently, Professor Havelock Charles has studied the bones of the lower limbs in the natives of the Punjab,[1] who habitually assume the squatting attitude. He confirms Professor Thomson's observations on the articular surface of the head of the tibia, and the additional facets at the tibio-astragalar joint. He also figures the retroversion of the head of the tibia, and describes modifications in the upper and lower articular ends of the femur, and in the acetabulum, all of which he associates with the squatting position.

It is obvious, therefore, that position and habit materially modify the forms of the bones, and that characters which MM. Collignon and Fraipont thought to be indicative of an inability to attain, in the full sense, the erect attitude, were due to the customary position of squatting, which both ancient and modern savages assumed when at rest. We have no evidence, therefore, that Quaternary man was not as capable of raising his body to the erect attitude as the men of the present day; and Professor Testut's observations further show that a tibia with a retroverted head may be associated with a skull of unusually high internal capacity.

Thus the retroversion of the head of the tibia, to which the above observers attached so much importance, is of no value as a proof of the existence of a transitional form between man and apes.

A few months ago, M. Eugène Dubois, surgeon in the army of the Indian Netherlands, published[2] a memoir descriptive of some bones recently found in Java. From the title of his work, "*Pithecanthropus erectus*, eine menschenähnliche uebergangsform," it is obvious that he considers he has established the existence of a link connecting together Apes and Man. He names this supposed link *Pithecanthropus erectus;* and as he believes it to differ in characters from Man on the one hand, and Apes on the other, he proposes to found a new family in the Primates, intermediate between *Simiidae* and *Hominidae*,

[1] *Journ. of Anat. and Phys.*, Oct. 1893, April 1894, vol. xxviii.

[2] Batavia, 1894.

to which he gives the name *Pithecanthropidae*. He defines the characters of this family as follows :—

Brain case, absolutely and in relation to the size of the body much more spacious than in *Simiidae*, but less spacious than in *Hominidae*: contents of the cranial cavity about two-thirds of the average contents of that of man; the slope forward of the occipital bone below the protuberance and superior curved line much stronger than in the *Simiidae*. Teeth, although retrogressing, yet of the type of the *Simiidae*. Femur, in its dimensions, like the human, and constructed for progression in the erect attitude.

He believes that the successive stages of evolution up to man are represented by the following forms :—*Protohylobates*, a primitive form of Hylobates; *Anthropopithecus sivalensis*, a form of Chimpanzee of the later Miocene or older Pliocene Period; *Pithecanthropus erectus*, a late Pliocene or early Pleistocene mammal; lastly, *Homo sapiens*.

The specimens on which these conclusions are based are a calvaria or skull-cap; an upper third molar tooth, which he says is the right; a left femur. They were procured in the neighbourhood of Trinil, in the district of Ngawi, in the Residency of Madiun, on the left bank of the river Bengawan in Java. In September 1891 the molar tooth was got about 1 metre below the dry season mark of the river. A month later, and 1 metre distant from the spot where the tooth was lying, and on the same level, the calvaria was found. In August of the following year, also during the dry season, and 15 metres (nearly 49 feet) higher up the stream, and on the same level, the left femur was excavated. During the dry season of 1893 search was made for other remains, but without result. The bones were embedded in the bank of the river from 12–15 metres below the plain in which the river had excavated its bed. The bank was formed of Pleistocene alluvial deposits, consisting largely of re-arranged andresite tuffs—the loose ejectamenta of volcanic eruptions.

M. Dubois has figured the three specimens, and his descriptions are accompanied with measurements. The examination of these interesting remains has obviously been methodically conducted, and the descriptions have been written with care and precision, so that, with the aid of the figures, one can obtain an

adequate conception of the characters of the bones. I am the more desirous to give my testimony to the care which has been bestowed on the descriptive part of the memoir, as I am not prepared to accept the conclusions arrived at. The author has also, at considerable length, instituted a comparison between the remains and the corresponding structures in anthropoid Apes and Man. I propose now to give a *résumé* of their character.

Skull-Cap.

This consists of the vault of the cranium from the glabella and supra-orbital arches in front to two finger-breadths below the occipital protuberance (inion) and superior curved line. It is a long ovoid, 185 mm. in glabello-occipital length; 130 mm. in its greatest transverse breadth; 90 mm. in breadth immediately behind the orbits, a dimension which, the author

Fig. 1. Profile view of the Java calvaria. Both figures 1 and 2 were traced from M. Dubois' drawings by Mr G. A. Rorie.

says, would probably have been 4 mm. greater in the unbroken skull. The highest point of the vault of the skull was in the parietal region, and was 62 mm. above a sagittal line drawn horizontally backwards from the glabella to the inferior curved line of the occiput. The relation of length to breadth was as 100 to 70, so that the skull was dolichocephalic. The supra-orbital ridges and glabella had great prominence, and the frontal sinuses were well developed. The greatest sagittal depth of a frontal sinus was 24 mm. The sagittal diameter of the cranial cavity was 155 mm. The thickness of the occipital bone a little below the inferior curved line was 4·5 mm. The frontal bone was slightly keeled in the line of the obliterated frontal suture,

and the other sutures of the cranial vault were obliterated. The general surface of the outer table of the skull was smooth, and there was an absence of bony ridges. The vault of the skull had an arch much below the European human skull, but higher than that of anthropoid Apes. The supra-inial part of the occipital bone sloped upwards and forwards from the inion, as in the Neanderthal skull, whilst the infra-inial part, to which the muscles of the back of the neck were attached, sloped downwards and

FIG. 2. Vertex view of the Java calvaria.

forwards to where the foramen magnum had been, though the actual position of this hole cannot be stated with certainty. The forward slope of the nuchal part of the occiput was, without doubt, in relation to the curve of the encephalon and the greater volume of the cerebrum in relation to the cerebellum, which one associates with the erect attitude. From the obliterated condition of the sutures the skull was obviously that of a person not below middle life. Dubois thinks, from the absence of ridges and

from the superior temporal lines on opposite sides of the skull being quite independent, that the cranium must have been that of a female. In the projection of the glabella and supra-orbital ridges the skull had, however, characters which one is accustomed to regard as masculine.

The cerebral cavity was, for the most part, filled with a stony mass, so that the capacity of the skull-cap could not be directly ascertained. Even if the calvaria had been free from its stony contents, the absence of the base of the skull would have made it impossible to obtain a direct determination of the entire cranial capacity.

From a comparison of the length, breadth, and arch of the vertex of the skulls of the Chimpanzee and of two specimens of Hylobates, with their actual capacity as determined by measurement, and from the measurements of the length, breadth, and arch of the vertex of the fossil, M. Dubois arrives at the conclusion that the actual capacity of the fossil cranium had been about 1000 cubic centimetres, that is, about double the capacity of the cranium of the gorilla, and about two-thirds of the capacity of a well-formed European cranium. Throughout his description, Dubois intersperses comparative observations on the crania of the Chimpanzee, Orang, Gorilla, Gibbon and Man. He does not appear to have had in his own possession the materials for comparison, with the exception of two skulls of the Gibbon and a female Chimpanzee; but he relies mainly on the published descriptions of Owen, Bischoff and Hartmann for the characters of the crania of the anthropoid Apes. Dubois recognises that the Java calvaria approximates more to the human type than to that of the anthropoid Apes; thus it is much more spacious, its vault is more highly arched, the supra-orbital arches are less projecting, the diameters generally are greater, and the downward and forward slope of the nuchal part of the occipital bone is more pronounced than in the Simiidae. Notwithstanding these human characters, he does not regard it as a human skull.

As the University Museum contains a number of examples of the crania of the larger anthropoid Apes, as well as a large collection of human crania, illustrating the different races of men, I have thought that it would be useful to compare Dubois' description and measurements with these specimens.

As regards the glabello-occipital length, the Java calvaria is 54 mm. longer than the mean of two Chimpanzee skulls, one of which is an old male; 54 mm. longer than a male Orang, and 65 mm. longer than a female Orang. It is more difficult to make a comparison with the skull of the Gorilla, as in this animal the strongly projecting occipital crest gives a length out of all proportion to the proper glabello-occipital diameter. Thus in a remarkably fine male, the glabello-cristal length is 217 mm.,

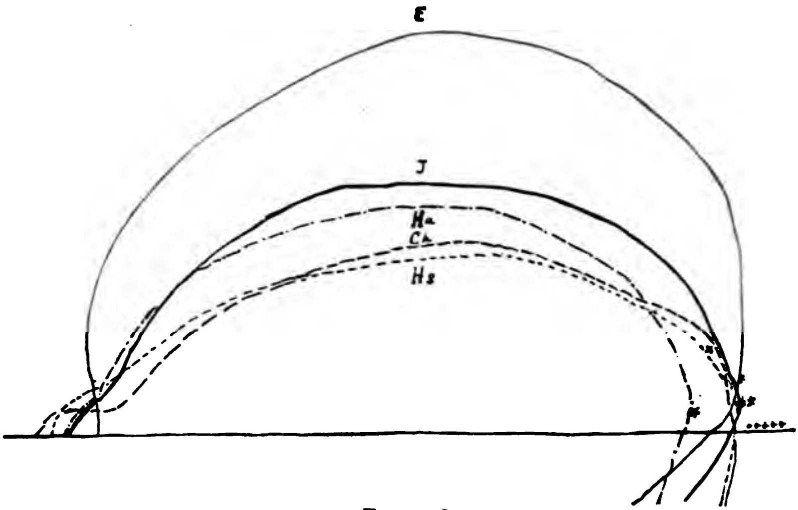


FIGURE 3.

J, profile outline of Java fossil; *E*, profile outline of European skull; *Ha*, of *Hylobates agilis*; *Hs*, of *Hylobates syndactylus*; *Ch*, of Chimpanzee (*Anthropopithecus troglodytes*). * Inion (posterior occipital protuberance); † Inferior curved line of occiput. Traced from M. Dubois' figure.

whilst in an adult female with a slight crest it is 153 mm., and in a young specimen, where the occipital crest is only just indicated, the long diameter is 132 mm.

In its greatest breadth the Java fossil is 32 mm. broader than the greatest mean breadth of the two Chimpanzees and the female Orang. It is 21 mm. broader than the mean of five adult male gorillas, 30 mm. broader than the female, 35 mm. broader than the young specimen. The breadth of the apes' skulls was taken in the squamous region.

The frontal diameter behind the orbits was, in the Java fossil, 20 mm. greater than in the Chimpanzees, and 28 mm. more

than in the Orangs. It was 19 mm. greater than the mean of five male Gorillas, 24 mm. greater than in a female Gorilla, and 22 mm. greater than in a young specimen. In the undamaged state of the Java fossil, as Dubois thinks, this diameter was probably 4 mm. greater than in the specimen as it now exists.

In the external dimensions of length and breadth, it is clear that the Java fossil is very much larger than the corresponding dimensions of the great anthropoid Apes, except as regards the length of the largest skulls in the male gorilla, which are so materially elongated by the development of the occipital crests.

Unfortunately, the height of the skull, owing to the want of the base, cannot be obtained by actual measurement.

Dubois draws a sagittal line between the most projecting part of the glabella and the inferior curved line of the occiput, and traces the profile outline of the Java specimen. He states that the highest point of the cranial vault is 62 mm. higher than the sagittal horizontal line, a dimension which, to the long diameter of the skull, is as about 1 to 3. His diagram of the profile of the Java specimen, in comparison with that of a European, two species of Hylobates and a Chimpanzee, is reproduced, p. 434, from which it will be seen that, although in its vault considerably lower than the European, it is, on the other hand, very appreciably higher than either the Chimpanzee or Gibbons.

In Table I. the dimensions of the Java calvaria and of the anthropoid Apes, which I have measured, is given:—

TABLE I.

	Age.	Sex.	Length.	Breadth.	Post Orb. Br.	Cub. Cap.
Java calvaria (*P. erectus* ?),	Ad.	?	185	130	90	1000 ?
Chimpanzee, . .	Ad.	♂	132	98	70	350
,, (*calvus* ?),	Ad.	♂	130	98	69	360
Orang, . . .	Ad.	♂	131	100	62	440
,, . . .	Ad.	♀	120	98	62	360
Gorilla, . . .	Ad.	♂	190	113	72	480
,, . . .	Ad.	♂	182	113	68	470
,, . . .	Ad.	♂	205	105	73	520
,, . . .	Ad.	♂	217	106	67	590
,, . . .	Ad.	♂	176	107	74	410
,, . . .	Ad.	♀	153	100	66	420
,, . . .	Young	?	132	95	68	355

In the apes the length was inio-glabellar, but in the Gorillas it included the crista occipitalis.

In comparing the length of the skull in the Java specimen with that of the anthropoid Apes, it must be kept in mind that, although in the Java fossil the glabellar projection is stronger than in human crania generally, yet that, neither absolutely nor relatively, is it so prominent as in the skulls of the Chimpanzee and Gorilla.

In my memoir on human crania, in the Report of H.M.S. *Challenger*,[1] I described a method of taking the internal capacity of the skull, which seemed to me to give more precise results than those of Broca and other craniologists. I have employed this method in the determination of the capacity of the crania of the anthropoid Apes, specified in Table I., and in taking the measurements I have on this, as on so many other occasions, been indebted to my Museum Assistant, Mr James Simpson. In that Table, the capacity of each skull is recorded. The adult male Gorillas ranged from 410 to 590 c.c., giving a mean of 494 c.c. The Java skull possessed, therefore, according to Dubois' estimate, twice the capacity of the mean of the five male Gorillas, and more than twice that of the female Gorilla. It was two and a half times as capacious as the mean of the two Orangs, and approached to three times the capacity of the skull of the Chimpanzee.

In comparing the Java specimen with human crania, M. Dubois almost entirely limits himself to a comparison with the European skull. It is obvious, however, that to obtain a proper conception of its affinities, the comparison should not be restricted to highly-developed European races, but rather it should be looked at side by side with a race now dwelling under savage conditions. There is no doubt that, as compared with a dominant European race, the cranial capacity of the Java specimen, if the accuracy of Dubois' estimate be accepted, is much below that of such a people, for example, as the modern Scot. Thus the capacity of the skulls of 50 Scotsmen in the University Museum, taken according to the method to which I have already referred, gave a mean of 1492·8 c.c., and ranged from 1770 to 1240 c.c.; that of 23 Scotswomen had a mean of 1325 c.c., and ranged from 1625 to 1100 c.c. The mean of the Scotsmen closely approximates to Welcker's measurements of

[1] Zoology, Challenger Expedition, part xxix. p. 9, 1884.

Europeans generally, quoted by Dubois, and places the fossil, in its capacity, as much below the European mean as it is above the mean capacity of the male Gorilla.

If we now take the aboriginal Australians as an example of the modern savage, we find them to be a low-typed, purely dolichocephalic race, presenting many features of correspondence with the Java specimen. The glabella and supra-orbital ridges are, in a large majority of Australian skulls, massive and projecting. A keel is not unfrequently found in the line of the obliterated frontal suture, and the vault of the cranium is, in many specimens, feebly arched. As regards the length of the skull, the mean glabello-occipital length of 25 Australian men was 190 mm., that of 13 women was 177 mm.—giving as the mean of the two sexes 183·5 mm., which almost exactly corresponds with the Java specimen. The greatest breadth of the Australian men was, on the average, 131 mm., and of the women 127 mm., so that the Java fossil practically corresponded in breadth to the men, and was slightly broader than in the women. The post-orbital frontal breadth was, on the average, 97·6 mm. in the men and 92 mm. in the women, which was slightly more than the breadth in the corresponding region in the fossil.

As regards internal capacity, it is very rare for an Australian skull to measure 1500 c.c., though I have measured a man from Queensland who reached 1514 c.c., one from the De Grey river 1450 c.c., and one from South Australia 1400 c.c. The average of 24 Australian men was, however, only 1286 c.c., and of 12 women 1106 c.c. In the men, no specimen was below 1000 c.c., but one was only 1044 c.c. In the women five specimens were below 1100 c.c., and three of these measured 930, 946, and 998 c.c. respectively. Granting, therefore, the accuracy of M. Dubois' estimate of 1000 c.c. for the fossil, and if it be as he supposes of the female sex, three Australian women were below it in capacity, and a considerable number were only a little more capacious.

In the skulls of other savage races in the University Museum, namely, Andaman Islanders, Admiralty Islanders, Bush people, Veddahs and hill tribes of India, I find 17 specimens ranging from 1000 to 1092 c.c. Two of these were probably males and the rest females. It follows, therefore, that a human cranium,

smaller in its capacity than 1100 c.c., is yet sufficiently large for the lodgment of a brain, competent to discharge the duties demanded by the life of a savage.

When the cranium is entire and the facial bones intact, there is comparatively little difficulty in arranging what the horizontal plane is to be in which a skull should be placed for the purpose of tracing its profile outline; but when the facial bones are absent and little more than the vault of the skull remains, it is a matter of much more difficulty to adjust the calvaria, so as to obtain a profile which will be in the horizontal plane of the head. From the previous description, it will have been seen that M. Dubois takes as his horizontal sagittal line one drawn from the most projecting part of the glabella to the inferior curved line of the occiput. This line cannot, however, be accepted, as being in the horizontal plane of the head, for it tilts the occipital bone upwards, and diminishes the slope downwards and forwards of the nuchal region of that bone. It lies also in its hinder part below the plane of the tentorium, and intersects the lower occipital fossæ in which the cerebellum is lodged. It is a question for consideration whether some other line cannot be devised which may give a more reliable basis for comparison.

If an antero-posterior horizontal section be made through the European skull from the nasion in front to the upper border of the grooves for the lateral sinuses in the occipital bone, the saw will in some specimens pass immediately below and parallel to the cribriform roof of the nose, and will open into the lower part of the frontal, and the upper part of the ethmoidal and sphenoidal air sinuses. In other specimens again it will enter the cranial cavity immediately above and parallel to the cribriform plate, and will not intersect the ethmoidal and sphenoidal air sinuses. It will also cut through the orbits just below their roof, and in some instances intersect the optic foramina and anterior clinoid processes. Further back it will divide the squamous-temporals just above the plane in which the superior borders of the petrous-temporals are placed, and will reach the occiput at the upper border of the lateral sinuses. The only parts of the cranial cavity in which cerebrum is situated below the plane of section, are the middle cranial fossæ, in which lie the tips of the temporo-sphenoidal lobes. The

posterior part of the section would lie almost in the plane of and close to the surface of the tentorium cerebelli, and the interval between the plane of section and the cranial vault practically represents the space which contains the cerebrum, the tips of the temporo-sphenoidal lobes being excepted. In any comparison therefore of the amount of cranial capacity for lodgment of cerebrum in different crania, the exact expression in a drawing or diagram of this plane of section is obviously of some importance.

We may now look to the surface of the skull to ascertain if it shows definite points both in front and behind which might be depicted in a profile drawing, and between which a horizontal line could be drawn to correspond with the antero-posterior plane above described.

The middle of the fronto-nasal suture, or nasion, is obviously the point which is required in front, and the posterior occipital protuberance, or inion, looks as if it might answer the purpose behind. It is necessary, however, to examine the skull and determine if the inion is precisely opposite the upper border of the groove for the lateral sinus. In the European skulls which I have tested I find, although occasionally the upper border of the lateral sinus is in the same horizontal plane as the inion, that more frequently it is above the inion; which protuberance is indeed usually opposite the lower border of the groove for the sinus. In cases where the inion is thick and very projecting I have seen it below the level of the lower border of the sinus.

Notwithstanding these variations it is obvious that a line drawn from nasion to inion, although it may not be precisely in the horizontal plane of the head, is yet less removed from that plane than the sagittal line of Dubois, and more exactly indicates the plane above which the cerebrum is lodged.

In some exotic crania in which the cavity had been opened, so that the relations of the groove for the sinus to the inion could be seen, similar variations were observed. In one skull from the Sandwich Islands[1] the inion was in a very marked way below the lower border of the groove for the lateral sinus.

With the aid of strips of soft lead moulded on to the cranial

[1] See section through this skull in Pl. VI. fig. 4 of my memoir on Human Crania in Challenger Reports.

vault, I have obtained the profile outlines of a number of crania, from the nasion backwards to the inion, and including the nuchal surface of the occiput when present.

In the accompanying diagram (fig. 4) several of these have been superimposed on each other, the nasio-inial line in each case having been placed for purposes of comparison in the horizontal plane of the drawing, so that the relative height of the cranial vault above that plane can be seen at a glance in the different specimens. The specimens selected are the Neanderthal skull; the Aberdeen skull, from the ancient Blackfriars Monastery (see p. 425); an Irish skull, from Askeaton Abbey, near Limerick; three Australian skulls—two men and a woman.

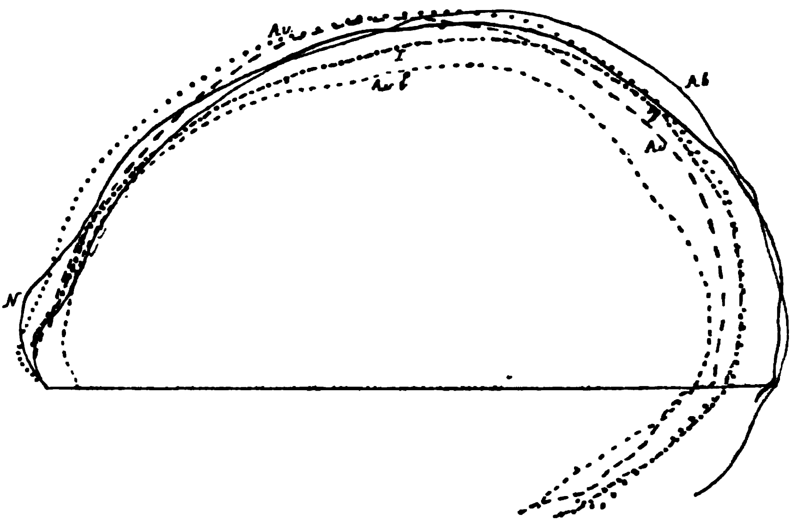


FIGURE 4.

The profile outline of each skull is represented by a characteristic line and letter. *N*, Neanderthal skull; *I*, Irish skull from Askeaton Abbey; *Ab*, Scotch skull from Aberdeen; *Au*, *Au*, two Australian men, one from the Wannon River district, Victoria, the other from Queensland; *Au* ♀, a female Australian skull from New South Wales.

The profile outlines of the crania depicted in this figure show that two specimens, namely, the female Australian and the Irish skull from Askeaton Abbey, are both lower in the curve of the vault than the Neanderthal skull; the skull from Aberdeen, in the frontal region, is also less arched than the Neander

man, though in the parietal region the vault is higher. In the Australian skull, from Queensland, the outline of the vault falls below the Neanderthal outline in the parieto-occipital and lower frontal region, though about the coronal suture the vault is higher. Certain measurements of these human crania contrasted with the Java fossil are given in the following table:—

TABLE II.

	Age.	Sex.	Length.	Breadth.	Post Orb. Br.	Cub. Cap.
Java calvaria (*P. erectus*?),	Ad.	?	185	130	90	1000?
Neanderthal calvaria, .	Ad.	♂	200	144	110	1230?
Aberdeen, " .	Ad.	♂	196	150	98	?
Irish (Askeaton) skull,	Ad.	♂	189	144	97	1390
Wannon River " Austral.,	Ad.	♂	192	124	90	1192
Queensland " "	Ad.	♂	177	130	94	1135
N. S. Wales " "	Ad.	♀	164	118	84	930

Upper Molar Tooth.

The isolated tooth was found 1 metre distant from the calvaria. The crown is described as forming an unequal triangle, with one lateral and two median rounded angles; the base was turned forwards and a little concave; the transverse diameter of the corona at the base was 15·3 mm., and the greatest sagittal diameter on the inner side was 11·3 mm. In the direction from before backwards it was very short. On the one side, the two anterior cusps were tolerably well developed, but on the other side the posterior median cusp was much reduced, and the postero-lateral scarcely developed. In consequence of this, the connecting band between the anterior median and the postero-lateral cusp did not exist, and the hollows of the grinding surface were quite irregular. This surface was only slightly worn in places. The tooth had two strongly diverging fangs, which projected somewhat obliquely backwards, the obliquity being due, M. Dubois thinks, to the fact that there had not been much space for the tooth in the sagittal diameter of the jaw. The median root measured from the neck 13 mm.; it was transversely compressed; the lateral root was 15 mm. long; on the inner side it was broadly and deeply forked, owing to the fusion of an anterior shorter, and a posterior longer fang, both of which

were compressed from before backwards. The form of the tooth indicated that, notwithstanding its great breadth, it had undergone a strong retrogression in the sagittal direction, which pointed to a corresponding retrogression in the entire dentary arcade. Dubois states that the tooth is larger than the corresponding molar in Man, and the grinding surface more rugose. On the other hand, it is not so strongly developed as in the Gorilla and Orang, nor so rugose.

In commenting on this description one is, in the first instance, disposed to raise the question whether the tooth belonged to the skull, the calvaria of which was found in its neighbourhood. From the fact that the grinding surface was only slightly worn, one would not be prepared to associate it with a skull, where all the sutures of the vault were so obliterated, as in the Java calvaria. As regards the size of its crown, I have compared it with the teeth of the anthropoid Apes in the University Museum. It is somewhat larger than the third upper molar in the skulls both of the Chimpanzee and Orang. In the adult male Orang the crown of the upper wisdom was 11 mm. in sagittal and 13 mm. in transverse diameter; in the female the corresponding diameters were 9 mm. and 12 mm. It is almost equal in size to the corresponding tooth in one of the male Gorillas, but it is distinctly smaller than in the three other males. Compared with the female Gorilla, its diameter in one direction is 1·3 mm. greater, and in the other 1·7 mm. less. It was distinctly larger than the upper wisdom tooth in Europeans. Compared with the corresponding tooth in a number of Australian skulls, it was also greater in the dimensions of its crown; but in a male skull, from the Riverina district of N. S. Wales, the transverse diameter of the crown of the corresponding tooth was as high as 14 mm., and the sagittal diameter, on the inner side, was 9 mm., and on the outer 10 mm. It is, I think, by no means clear that this tooth is from a human jaw, and is not rather that of an anthropoid Ape. That it belonged to a Gorilla or Chimpanzee is out of the question, as these apes are African and not Asiatic in their habitat. The question arises if it may not have been that of a large Orang, in which case the area occupied by this ape would have been more extensive than Borneo and Sumatra, its present habitat, and would have included Java.

The general configuration of the crown is indeed not unlike that of the wisdom tooth of an adult Orang; though, without having the tooth before one for examination and comparison, one does not wish to express too positive an opinion.[1]

Left Femur.

This isolated bone was found nearly 50 feet higher up the river bank than the calvaria. It was only slightly injured, at the head, great trochanter and the lower articular ends. It had, however, a large irregular pointed exostosis, growing from the inner and back part of the shaft, below the small trochanter. It was an adult bone, and its surface was not smoothed down by friction against extraneous objects. Its length from the highest point of the head to a line connecting the lowest points of the two condyles was 455 mm. In his description of the bone, M. Dubois recognises many features of correspondence with the human femur; in the shape of the head, that of the trochanters and of the anterior inter-trochanteric line; in the development of the ridge for the insertion of the gluteus maximus; in the angle formed by the neck with the shaft, in the compression of the neck, in the form of the lower articular end, and of the inter-condyloid fossa, and in the presence of a linea aspera, it repeats the human characters, so much so, indeed, that Dubois has no hesitation in concluding that the femur could be extended, both on the trunk and leg, as to admit of the erect attitude.

On the other hand, he states that it differs from the human thigh bone, in the absence of an *angulus medialis* or line separating the anterior convex surface from the inner surface; in the inner surface being convex and not concave; in the popliteal surface having less definite lateral boundaries, and being somewhat convex and not flat, whilst the inter-trochanteric crest is less elevated, narrower and turned inwards, so that this line is not straight, but concave. These supposed points of difference are, he considers, of sufficient moment to distinguish it from the human bone, and to approximate it to the femur of anthropoid Apes. In arriving at this conclusion, M. Dubois has not had before him, for purposes of comparison, a sufficient number of

[1] I observe that in a discussion which took place at the meeting of the Anatomical Society, Feb. 13, 1895, Dr Arthur Keith expressed the opinion that the tooth was that of an Orang.

human femora, and has not realised the variations which occur in the bone in those areas where he conceives that the Java specimen differs from the femur in Man. From the examination of a large number of femora, both European and exotic, I am able to state that the characters which Dubois considers not to be human are occasional varieties in the femur of Man, so that they lose all significance as marks of differentiation from the human femur.

There can be no doubt that the Java femur is a human bone, but whether it is the thigh bone of the skeleton to which the calvaria belonged is, I think, extremely doubtful. The distance at which it was found from the skull-cap and the fact that it was lying in an alluvium brought down in the course of a tropical river, show that the remains were only loosely associated with each other, and had not of necessity any organic connection. The sharpness of its contours and of the pointed exostosis are characters which it is difficult to reconcile with the condition presented by the calvaria. On the supposition that it was of the same age as the calvaria, as to which, however, there is, I think, some doubt, it showed few signs of rubbing or injury as compared with what the skull itself had suffered. Consequently, I am not disposed to think that the characters of the femur are of any moment in our interpretation of the skull-cap, which must be weighed on its own merits.

In the projection of the supra-orbital ridges and glabella, and in the shape of the occipital region, the Java calvaria bears such a resemblance to the Neanderthal skull that, the latter being regarded as human, one sees no reason why, in these respects, the Java fossil should not likewise be human. In both, also, the cranial vault has a low arch, though M. Dubois considers that, in this respect and in the internal capacity, the fossil is below the skull from the Neander Valley. As regards the capacity, the injured state of the specimen only admits of an approximate estimate, but, on the basis that it was about 1000 c.c., sufficient evidence has been adduced in this communication to show that, in the dolichocephalic aborigines of Australia, the crania in a number of instances were only slightly above that figure, and in some even below it, whilst in other savage races, an equally low capacity is occasionally found. In my judgment, therefore, there

is nothing in this character to lead one to say that the skull was not a human skull. If we accept the view that the Pleistocene deposit in Java, in which this specimen was found, is of the same geologic age as the European Pleistocene, there is nothing in the configuration of the skull-cap to place it in a different category from those remains of human Quaternary Man obtained in Europe, which have already been referred to as possessing similar characters.

From the above criticism it will be seen that I am unable to accept M. Dubois' opinion that we have in these remains evidence of a new genus and species intermediate between Man and Apes. The existence of such a transitional form is still a matter of speculation, and has not been placed on the basis of ascertained fact.

[About the time when this communication was made to the Royal Society of Edinburgh, other naturalists were engaged in criticising M. Dubois' memoir and conclusions. In *L'Anthropologie*, Tome vi. No. 1, p. 65, Jan.–Feb. 1895, M. A. Pettit reviewed the memoir, and obviously inclined to the opinion that the remains were human. He thinks that the cranial capacity had been underestimated, and was possibly as high as 1200 c.c. In a communication made to the Anatomical Society (*Proceedings*, Feb. 13, p. xviii), Professor Cunningham stated that he had no doubt that the skull and femur were both human.]

ON THE MOVEMENTS OF THE METACARPO-PHALANGEAL JOINT OF THE THUMB. By F. G. Parsons, F.R.C.S., *Demonstrator of Anatomy to St Thomas's Hospital, The Embankment, London.*

The range of movement of the metacarpo-phalangeal joint of the thumb is known to vary to a great extent in different individuals, but I am not aware that any series of observations dealing with the amount of this variation has been recorded. In the present paper I shall give an account of measurements in 187 individuals, with a view to testing the range of variation, the average amount of flexion allowed, the difference between the two sides, and the influence exerted by sex, age, and occupation. I make no apology for publishing the full list of measurements, because these are the facts on which my deductions are based; besides which, now that the study of variation is attracting so much attention, the collection of facts may to some be of more value than the inferences drawn from them.

In every case I have looked for the presence or absence of the extensor primi internodii pollicis, which is fairly easy to determine in a man's hand, but in the hands of many women it is often impossible to satisfy oneself as to whether the muscle is present or not. For this reason I have only recorded its absence in those cases in which I was fairly certain about it, but the observations are quite sufficient to make me sure that the presence or absence of the extensor primi internodii has nothing to do with the amount of movement allowed in the joint.[1]

For the opportunity of taking a series of measurements on the thumbs of out-patients I am indebted to the kindness of Dr Toller and Mr Abbott of this Hospital.

[1] In those cases in which no remark is made, the muscle was either present or a satisfactory observation beyond my powers.

Extreme flexion of thumb allowed in 30 Medical Students.

L.	R.		L.	R.	
58°	50°		60°	63°	
80	72		60	72	
69	69		59	56	E.P.I. slight.
60	60		37	26	
50	50		40	32	
34	32	E.P.I. slight.	38	44	
76	75		49	49	
54	58		60	55	
66	66		55	55	
55	42	E.P.I. absent.	55	53	
63	50		73	55	
60	65		28	35	
67	53		55	48	
61	55		67	67	
79	79		85	78	

In 87 Male Out-Patients over 15.

L.	R.		L.	R.	
65°	63°		70°	48°	
45	42		62	60	
25	25		48	58	
62	58		50	55	
50	32		45	35	
60	60		40	35	
60	70		45	45	
45	60		55	50	
52	60		45	58	
58	65		60	60	
40	35		48	53	
42	45		65	60	
58	57		50	55	E.P.I. absent.
55	55		68	80	
48	65		30	30	E.P.I. well marked.
68	79	E.P.I. slight.	40	35	
65	60		52	45	E.P.I. absent.
50	50		35	35	
70	75		45	35	
45	55		52	52	
78	60		55	50	E.P.I. slight.
45	45		40	40	
45	35		45	30	
48	45		65	65	
50	50		60	65	
68	65		60	60	
70	65		80	62	
65	70		58	58	

L.	R.		L.	R.	
40°	40°		60°	55°	
35	40		58	50	
33	30	E.P.I. absent.	38	28	
60	60		50	55	
72	70		64	62	
57	58		35	32	
55	45		28	29	
47	47		42	42	
32	25		62	65	
67	55		55	50	
58	58	E.P.I. absent.	75	78	
60	62		60	60	
40	45		55	50	
50	52		45	52	
52	57		62	62	
55	58				

In 42 Female Out-Patients over 15.

L.	R.		L.	R.	
70°	55°		68°	63°	
70	64		90	75	
62	45		54	50	
68	70		55	55	
52	55		50	50	
51	62		48	42	
62	52		52	45	
58	58		88	76	
55	57		72	65	
18	48		68	62	
50	50		45	40	
65	70		45	45	
45	35		70	75	
50	55	E.P.I. absent?	70	75	
45	45		52	62	E.P.I. absent.
45	50		38	38	
67	65		65	60	
60	55		60	68	E.P.I. absent.
60	55		68	50	
80	80		70	70	
65	45		60	55	

In 28 Children under 15.

L.	R.		L.	R.	
80°	75°	æt. 4.	57°	45°	æt. 14.
70	65	æt. 11.	35	30	æt. 13.
70	55	æt. 9.	62	52	æt. 14.
82	65	æt. 8.	65	65	æt. 7.
70	80	æt. 11.	47	55	æt. 13.

L.	R.	L.	R.
70°	62° æt. 8.	60°	65° æt. 4.
80	85 æt. 4.	55	53 æt. 12.
58	40 æt. 14.	67	60 æt. 12.
68	68 æt. 14.	76	65 æt. 8.
68	56 æt. 10.	55	50 æt. 12.
55	57 æt. 12.	55	60 æt. 10.
40	40 æt. 13.	70	68 æt. 10.
40	35 æt. 8.	40	40 æt. 11.
72	55 æt. 11.	65	65 æt. 12.

A consideration of these figures shows, in the first place, that there is often a great difference between the amount of flexion allowed on the right and left sides; thus, out of the total number of cases, 73, or 39 per cent., are alike, or within three degrees of one another; and although it is by no means always the case, in the greater number of instances the left thumb is more movable than the right, the average amount of flexion on the left side being 56°, while on the right it is 53°.

Macalister[1] gives 68° as the normal, but my observations work out at a lower figure.

A mere average of the cases, however, does not give a fair idea of the normal, and, of course, it gives no idea at all of the extent or frequence of the variations. For this reason I have prepared charts of all the measurements in both hands; in these each dot represents a measurement, while the degrees of flexion are only marked in multiples of five, partly for the sake of simplicity, and partly because I have noticed that two observers will differ to the extent of one or two degrees in measuring the angle of the same thumb. A glance at either of the charts on p. 450 will show that, although the mathematical average may be 56° for the left hand and 53° for the right, as a matter of fact more thumbs measured 60° (58° to 62°) than any other figure. The charts also show that the range of variation extends over 70°, the most flexible thumbs bending 90°, the least flexible 20°. The variation seems to be greater in the left hand than in the right, as in the latter chart the dots are more closely massed round the 60°.

The average amount of flexion for the 117 males works out at 54° for the left hand and 52° for the right, while the average

[1] *Text-book of Human Anatomy*, p. 163.

Chart No. 1. Left Hand.

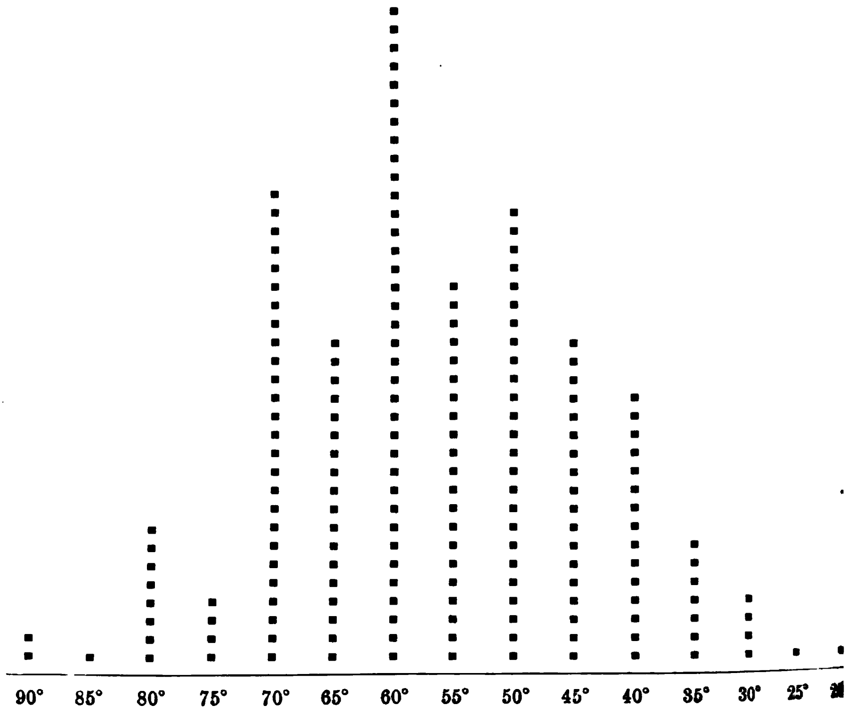
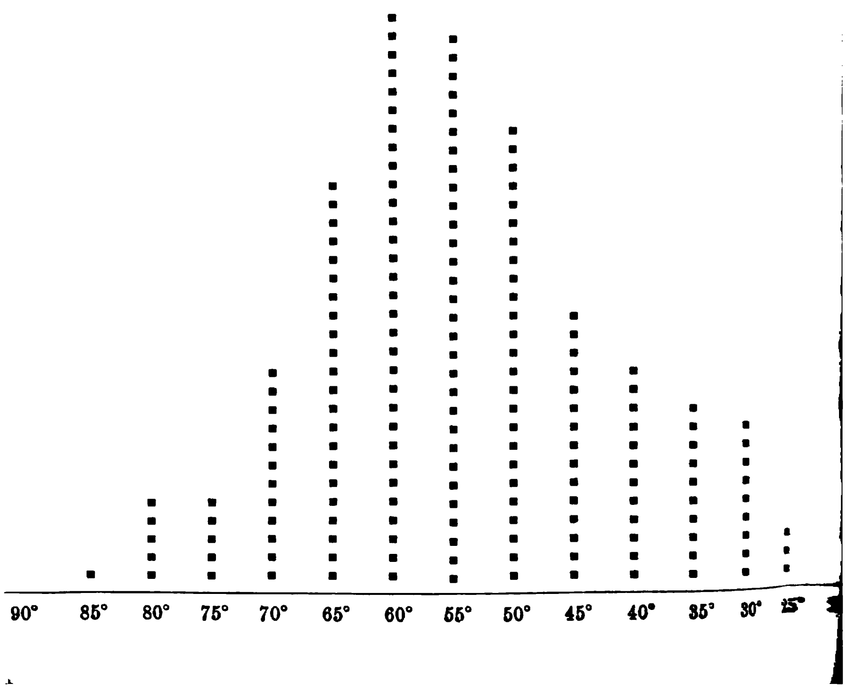


Chart No. 2. Right Hand.



for the 42 females comes to L. 59° R. 57°, showing that female thumbs are, as a rule, more flexible than male. Of these 117 adult males, 87 were out-patients belonging to the labouring classes, while 30 were medical students. The average flexion of the former is L. 53° R. 52°, of the latter L. 58° R. 55°, pointing to the fact that manual labour tends to decrease the mobility of the metacarpo-phalangeal joint of the thumb to the extent of 4° or 5°. This conclusion is further pointed to by the average of the 28 children under 15 years of age, which comes to L. 61° R. 57°. If the details of these children be referred to it will be found that the younger ones have, as a rule, the greatest mobility of the joint, while those nearing 15, who are probably at work, approach more nearly the adult standard.

With a view to determining the anatomical appearances, I dissected the most flexible and the most inflexible thumb which was present in the dissecting-room. In each case I found, as Humphry[1] states, that flexion was checked by the posterior fibres of the lateral ligaments. I also found that the amount of movement gave a characteristic appearance to the head of the metacarpal bone. In the inflexible thumb the part of the head on which the phalanx rested was nearly flat, and its surface was directed almost at right angles to that for the sesamoid bones. In the flexible thumb the surface for the phalanx formed a perfectly even curve with that for the sesamoid bones.

To sum up. The results of my observations on these 187 pairs of joints are:—

1. That the amount of flexion at the metacarpo-phalangeal joint varies from 20° to 90°.

2. That the left thumb is, on an average, 3° or 4° more movable than the right.

3. That the thumbs of women are more movable than those of men, as a rule.

4. That the thumbs of labouring men are less movable than those of men belonging to the non-labouring classes.

[1] *Human Skeleton*, p. 434.

5. That the thumbs of children, especially of young children, are more movable than those of men or women.

6. That manual labour tends to decrease the mobility of the joint by 4° or 5°.

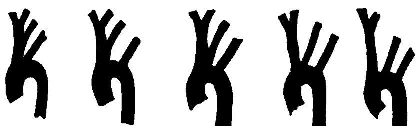
7. That the limitation of flexion is due to the ligaments, and that the head of the metacarpal bone adapts itself to the amount of movement allowed.

Since the above averages were worked out I have taken several further measurements, but as they point to exactly the same results I have hesitated to make the paper more cumbrous than is necessary. The question of the effects of left-handedness and of special occupations I must leave until I can get sufficient observations to found conclusions upon.

THE MODES OF ORIGIN OF THE CAROTID AND SUBCLAVIAN ARTERIES FROM THE ARCH OF THE AORTA IN SOME OF THE HIGHER PRIMATES.

By ARTHUR KEITH, M.D., F.R.C.S.

1. *A Tabular Statement.*—Our knowledge of the less common modes in which the carotid and subclavian arteries take their origin from the arch of the aorta, is in Man fairly complete; but in the higher Primates, as may be seen from the accompanying Table, it is comparatively scanty.



	A	B	C	D	E	Other varieties.
500 cases.[1]	...	53	...	...	441	6
Man, 187 cases,[2] . .	...	7	...	15	161	4
Gorilla, 9 cases,[3] . .	...	...	1	...	8	...
Chimpanzee, 11 cases,	...	...	3	...	7	1
Orang, 15 cases, . .	...	1	11	3	...	...
Gibbon, 20 cases, . .	...	10	7	3	...	...
Semnopithecus cinereus and femoralis, 23 cases, ...	9	14	...	...	...	...
Macacus namestrinus cynomolgus and aretoides, 22 cases,	13	7	2	...	...	...
Mycetes, 3 cases, . .	...	2	...	...	1	...
Ateles, 3 cases, . .	3	...	3	...	...	...

2. *The various types form a series.*—The table shows that the prevailing combinations of aortic arch branches, found in this group of animals, constitute a series which may be regarded as progressing from the type A to the type E. In the type A, the four pre-aortic trunks arise from the aortic arch by an almost

[1] "Third Annual Report of the Committee of Collective Investigation of the Anat. Soc.," *Journ. Anat. and Phys.*, 1893, vol. xxvii. p. 191.

[2] *The Anatomy of the Arteries of the Human Body*, Richard Quain, 1844.

[3] The various sources from which these cases were obtained will be found in the reference literature added to this paper. Descriptions of two orangs, ten gibbons, and the cynomorphous monkeys are from dissections made by myself. The four specimens in the Museum of the Royal College of Surgeons, London, of the aortic arches of the gorilla, chimpanzee, orang, and gibbon are also included.

common origin; in type B, the left subclavian has moved its origin some distance from the innominate, and the left carotid has made some approach towards taking its origin directly from the aorta; while the types C, D, and E apparently represent further stages of a migratory tendency in the same direction. This series finds its natural climax when the right carotid also reaches down and takes an independent origin from the aorta. The rare human anomaly of a right external carotid taking a direct origin from the arch also belongs to this series. The anomalous arrangement, found in a chimpanzee by Chapman, where the left carotid arose with the left subclavian from a short left innominate trunk, we may regard as an instance in which the left carotid had not only moved towards but actually fused with the left subclavian. Such an origin for the left carotid will probably be found to occur as a prevailing variation in the chimpanzee, for in another individual of that genus an approximation to this condition was observed.

3. *How the various types may be brought about by modifications of the early fœtal representatives of a visceral-arch arterial system.*—In 1862 Sir William Turner[1] accounted for the various forms in which the primary branches of the aortic arch are combined, by the modifications which the precursors of these vessels underwent, during the transmigration of the heart thoracicwards. The explanation then offered still holds good, although the subsequent contributions of Professor His[2] and Professor Yule Mackay[3] have amplified our knowledge of the early fœtal arrangement *and relationship* of the pre-cardiac vessels. These vessels—representatives of the visceral-arch system—in the human embryo of the second month, radiate from the dilated extremity of the *truncus arteriosus* pretty much like the fingers of a glove,—the future aorta, of course, being one of the emerging vessels. The dilated extremity of

[1] "On the irregularities of the pulmonary artery, arch of the aorta, and the primary branches of the arch, with an attempt to illustrate their mode of origin by a reference to development," *Brit. and For. Med. and Chirurg. Rev.*, vol. xxx., 1862, pp. 173 and 446.

[2] *Anatomie Menschlicher Embryonen*, Leipzig, 1880.

[3] "The development of the branchial arterial arches in birds, with special reference to the origins of the subclavian and carotid arteries," *Phil. Trans.*, 1888, part 2, vol. 179.

the *truncus arteriosus* may be correctly enough regarded as made up of the fused basal ends of the arteries of the visceral arches, and it is out of this common basal part, during the retrogression of the heart, that the basal parts of the future common carotid and subclavian arteries are carved. The various typical arrangements, in which the primary branches of the arch of the aorta occur in the higher Primates, may be accounted for by the amount of inter-arterial cleavage.

4. *Why the various forms?*—The type prevailing in each genus in all probability best serves the body-economy of that genus, but how it does so is by no means clear. Sir Richard Owen concluded that the origins of the left subclavian and carotid arteries moved distalwards on the aortic arch as the transverse diameter of the chest relatively increased. That this tendency is associated with such an increase is strongly suggested by the arrangement of the primary branches of the aortic arch in such animals as the seal, beaver, manatee, bat, howler, chimpanzee, gorilla, and man; but, if the chest measurements afforded by articulated skeletons are to be relied upon, the differences between the chest diameters of the gibbon and orang on the one hand, and the gorilla and chimpanzee on the other, are insufficient to account for the disparity in the arrangement of the aortic arch trunks in these animals. Touching this matter, it would be well to observe if the cynomorphous arrangement, when it occurs in Man, is accompanied by any approximation to the cynomorphous form of chest. It is doubtful if one can legitimately construe this apparently cynomorphous reversion in the arrangement of the primary branches of the aortic arch in Man as an atavistic tendency: more probably it has no more morphological worth than the degree of interdigital webbing.

5. *Atypical origins of the left vertebral and thyroidea ima arteries.*—Although in about 6 per cent. of men the left vertebral artery has its origin transferred to the arch of the aorta, it was not thus found in even one of the *primate* dissections above enumerated. Herein lies one tendency, in its frequency at least, peculiarly human.

The *thyroidea ima,* however, arose from the aortic arch in one chimpanzee, and from the left carotid artery in one gorilla,

four gibbons, three semnopithecques, and two macacques. In some of the two genera last mentioned it arose from the carotid artery in the neck, so that it is hard to distinguish between this form proper and a detached branch of the superior thyroid. In fact, the fork between the carotids, which represents the bifurcation of the primitive ventral aortæ, forms a partial ellipse upon which the origin of this artery may course.

6. *On the study of variations, in general, and the study of the variations in the arrangement of the primary branches of the aortic arch, in particular.*—An extended observation will probably show that nearly-allied races are more emphatically distinguished by the kind and frequency of their anatomical variations than by what would be described as their typical structure. What little we know of the anatomy of the negroid races brings out this fact prominently; for although in typical structure the white and negroid races agree, yet in the character and frequency of their variations from that type, they differ markedly. For instance, the cynomorphous arrangement of the primary branches of the aortic arch occurs as a variety in the negroid races with thrice the frequency found in the white races. At any rate, fifty other points, osteological, cerebral, and myological, could be cited to prove that the example given is not an isolated instance, but part of a general characteristic of the negroid race. While investigating the anatomy of the Hylobates recently, the frequency and even character of the variations in structure of the Siamang were, I found, strikingly different from those of the other gibbons.

In working out the conditions which accompany and surround human anatomical variations, assistance is likely to be obtained by a much extended investigation into the anatomy of the higher Primates. If the theory of descent be true, we may regard the animals that, structurally, most nearly approximate to Man as control experiments launched by Nature, upon which we may test our speculations as to the causes of human variations. To that end it is necessary to give, with each record published, an exact inventory of the amount of material used. The method of taking an anatomical census of the race has long supplanted the old manner of describing single individuals selected as types, as far as human anatomy is concerned, but the

newer system has yet to be applied to other animals. A type has rightly come to be recognised as a mental realisation, with no bone and flesh embodiment; whereas, by applying the newer anatomical methods, the race becomes, as it were, a great amœboid form, with its preponderating variations thrown out as pseudopodia feeling towards adaptation.

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A RARE ABNORMAL ARRANGEMENT OF THE CARDIAC CORONARY ARTERIES.

By DAVID HEPBURN, M.D., F.R.S.E., *Lecturer on Regional Anatomy and Senior Demonstrator of Anatomy in the University of Edinburgh.*

ABNORMALITIES of the coronary arteries of the heart are not of frequent occurrence, and when they do appear they usually take the form of an increase in the number of these vessels. The simplest variety of this increase in number is figured in Plate I. of Quain's *Abnormalities of the Arteries*, where a small additional right coronary artery springs from the sinus of Valsalva, alongside of the normal right coronary artery. The explanation of such an additional artery is, that it merely represents an independent origin for a normal branch of the right coronary artery. With such supplementary branches this is the natural explanation.

Cases are recorded in which the number of coronary arteries is reduced—that is to say, both may arise from a common trunk; and a variety (which is more of the nature of a pathological curiosity) is recorded by St John Brooks[1] in which branches from the left subclavian artery, the right coronary artery, and the pulmonary artery anastomosed to form a cirsoid mass.

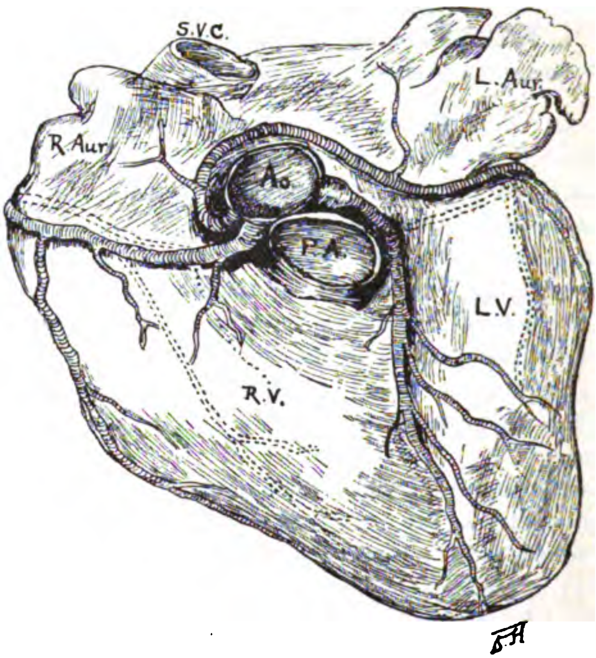
In the following statement I wish to record an abnormality which consisted of an increase in the number of vessels, viz., three, each of which had an independent origin from the aorta. Bochdalek[2] describes a case in which three arteries sprang from a common trunk: one took the course of a normal right coronary artery; a second, after passing behind the aortic root, came forward to the front of the left auricle, and completed its course as a defective left coronary artery; while the third descended in front of the heart, supplying those branches which were absent from the branch doing duty for the left coronary artery.

I refer specially to this case because in the one which has come under my notice the additional vessel also supplies deficiencies in the distribution of the left coronary artery.

[1] *Jour. Anat. and Phys.*, vol. xx. p. 26, Pl. II.

[2] "Anomaler Verlauf der Kranzarterien des Herzen," *Arch. f. path. Anat.*, &c. (Virchow), Berlin, 1867, Band xli.

The subject was a male undergoing dissection in the University Practical Anatomy Rooms.



Semidiagrammatic view of the Heart to illustrate the origin and course of the abnormal Coronary Artery. S.V.C., superior vena cava; Ao., aorta; P.A., pulmonary artery; R. Aur., right auricle; L. Aur., left auricle; R.V., right ventricle; L.V., left ventricle. The dotted lines express the course of the vessels on the posterior surface of the heart.

The three coronary arteries given off by the aorta were all of fairly equal diameter at their points of origin. Two arose independently from the anterior sinus of Valsalva, and the third took origin from the left posterior sinus of Valsalva. The latter, corresponding in origin to the normal left coronary artery, passed obliquely downwards, and appeared at the left side of the pulmonary artery, between it and the appendix of the left auricle. Its further course was downwards towards the apex of the heart in the anterior interventricular groove, supplying muscular branches as it proceeded. So far, therefore, it represented a left

coronary artery from which the circumflex or posterior portion was wanting.

The artery representing the right coronary artery was practically normal as regards its distribution. It arose from the anterior sinus of Valsalva, and appeared to the right of the pulmonary artery. Thereafter it travelled in the right auriculo-ventricular groove towards the right border of the heart, giving off as it went muscular branches to the right border of the right ventricle. Turning round the right border of the heart it passed towards the left side, still in the auriculo-ventricular groove, and gradually dwindled in size. It supplied the usual posterior branch along the posterior interventricular groove towards the apex.

The third vessel supplied the deficiencies already noted in the foregoing left coronary artery, and its course practically corresponded with that of the *second* of the three branches described by Bochdalek.[1] In calibre it quite equalled either of the vessels already described. It arose from the anterior sinus of Valsalva, to the right of the other vessel springing from the same sinus. At first it coursed backwards between the aortic root and the right auricle, supplying branches to the posterior aspect of the auricle as it went. Continuing its course, the vessel passed posterior to the ascending aorta and the main trunk of the pulmonary artery. Thereafter the vessel turned forwards between the pulmonary artery and the appendix of the left auricle, and appeared to the left side of the defective left coronary artery, where it entered the left auriculo-ventricular groove, and pursued its course towards the left border of the heart in front of the left auricle. Having reached the posterior aspect of the heart, this vessel continued in the auriculo-ventricular groove, giving off branches to the wall of the left ventricle as it proceeded. This curious vessel may therefore be regarded as supplementary to the left coronary artery, which had its normal origin, although defective in its distribution. It resembles the second branch of Bochdalek's case, already referred to, in its main features, except that it had an independent origin and its main branches of distribution were upon the posterior aspect of the left ventricle. The third branch in Bochdalek's case had the origin common to

[1] *Q.v.*

the other two, was smaller in size, and descended in the anterior interventricular groove, so that it and the defective left coronary artery in the present description closely resembled each other except in their respective points of origin.

The cardiac veins were in a dilapidated and fragmentary state before the part was brought under my notice, but, so far as I could determine, there was no irregularity in their return to the coronary sinus.

REPORT ON RECENT TERATOLOGICAL LITERATURE. By BERTRAM C. A. WINDLE, D.Sc., M.D., M.A., *Professor of Anatomy in Mason College, Birmingham.*

IN this fifth report on Teratological Literature, the writer has proceeded on similar lines to those of former years. He has again to express his indebtedness to those authors who have been good enough to send him copies of their papers, and to request them and others to be so kind as to supply him with any further communications dealing with the subject for use in the preparation of future reports.

GENERAL.—Giacomini (I.) narrates a series of experiments, the object of which was to ascertain the influence of differences of barometric pressure upon the development of eggs. He points out that the pressure must vary enormously in the cases of birds which make their nest upon the plains, and those which build at high altitudes; but in his experiments, he has reduced the pressure far below that which can exist under any normal circumstances. The apparatus which he used in his experiments is figured, and consisted of an incubator capable of being hermetically sealed, save for the apertures for the admission and escape of the rarefied air which was drawn through it by means of a water aspirator. The air passed through mercury to diminish the pressure, and subsequently through water and sulphuric acid to rid it of any impurities. In the first series of experiments, the sixteen eggs were hermetically sealed up in the incubator, and a current of air introduced at a pressure of from 16 to 17 cm. of mercury. Six other eggs, incubated at the same time in another part of the same apparatus, but at the normal pressure of the air, served as controls. The eggs were examined on the fourth day, when all the controls were found in a normal condition, whilst all the others were arrested. In subsequent experiments, under similar conditions, the result was never so definite as on this occasion; but in other cases, the embryos were too small for the period at which they had arrived, the area vasculosa formation was deficient, the blood-islands being arrested in their development and too few in number.[1]

In the second series of experiments the eggs were placed as before, but in stagnant air and with undiminished pressure. As the apparatus was opened every day for the purpose of turning the eggs, &c., the air was then renewed. On the fourth day they were opened and found to be normal, thus proving that the previous abnormalities had

[1] This is another example of the fact to which I have already called attention in a paper in this *Journal*, vol. xxvii. p. 436, that whatever the nature of the disturbance applied to the developing embryo, the results which follow are in many cases, if not in most (I think one can now say most), absolutely identical, and that these effects, for the most part, manifest themselves in connection with the area vasculosa and the mesenchymatous region.

not been connected with the incubator. In the third series, the pressure was reduced to from 26 to 27 cm. of mercury; a litre of pure oxygen was then introduced and the pressure reduced to 16 to 17 cm. On subsequent days the incubator was opened, the pressure reduced, and the oxygen admitted as on the first. On the fourth day all the eggs were opened and found to present the appearances of eggs which had been exposed to an excess of oxygen. The areæ vasculosæ were large, the vessels distended, and the blood of a bright red colour. In the fourth series, incubation was allowed to proceed in a normal manner up to the fourth day, when the pressure was reduced to 16 cm. Two days after the eggs were opened: in five the embryos were dead, that in the sixth being still alive. They presented all the signs of asphyxia, the blood being dark red, and the areæ vasculosæ having numerous extravasations. In the living embryo the allantois was little developed, the heart was beating very slowly, and the blood was venous in character. That the results were not due to poisoning from the mercury or sulphuric acid was proved by experiments, in which these substances were used without lowered pressure, and incubation proceeded normally.

Féré (II.) describes the action of certain substances of a narcotic or anæsthetic nature on the development of eggs. The exposure of eggs to the vapours of ether or chloroform may suspend the development without completely arresting it. Exposure to the vapours of essence of turpentine, lavender, aniseed, clove, absinthe may cause a simple delay in the process of development, or a complete absence of development, or the production of monstrosities. There are examples of immunity, development then being normal, both from the morphological and chronological points of view. It is interesting to note that the greater part of the agents which exercise a disturbing influence upon the development of the egg, have a similar action with regard to certain microbes and to mushrooms. In his experiments with tobacco, the author states that it is necessary to take into account, on the one hand, its directly toxic action, producing defects of development, and, on the other, of the mechanical effect produced by the smoke, which, depositing itself upon the egg, acts as a varnish, which decreases the permeability of the shell by the air.

Giacomini (III.), continuing his observations upon early human embryos, describes a case in which defective formation of the amnion coincided with an atrophic condition of the embryo. (It will be remembered that under this title he includes forms in which the organs of the embryo, or some of them, though profoundly altered, are still recognisable.) The mother had frequently aborted, probably from a chronic endometritis. On opening the chorion no traces of an embryo were observable; but on making a series of microscopic sections, the umbilical vesicle, with traces of some of the organs of the embryo, were clearly to be made out. In the latter, the numerous round cells, so characteristic of these forms, were as usual present. The cephalic extremity was covered with magma reticularis without any amnion. The author attributes the absence of this membrane to a failure in development, and not to an atrophic process, a view which

is rendered more certain by the fact that the amnion was present in sections passing through the caudal end of the embryo. He devotes some space to considering different views respecting the amnion, and thinks that his case fits in with the theory of Pockels as to the relations of the embryo and the amnion, and that in his specimen, whether on account of its early age or of its abnormal condition, the former had penetrated into the latter only at its caudal and dorsal regions, whilst the head was still placed outside.

Valenti (IV.) describes an atrophic embryo from a female who was three months pregnant, noting that no human embryo from so late a period of gestation has yet been described in so advanced a condition of atrophy. The chorion had many cysts, the presence of which he thinks accounts for the atrophic condition. In the much reduced embryo could be recognised, with some assistance from the imagination, the remains of the neural canal. The umbilical cord was unusually well developed for a fœtus of this description.

Gade (V.) describes a case of anencephaly with other malformations. The mother had previously borne two anencephalous fœtuses. In this case there was also bilateral microphthalmy, union of the lips, lordosis of the lumbar region with atrophy of several vertebræ, aplasia of the twelfth pair of ribs, union of the two kidneys, dislocation of the large intestine and atresia ano-vulvalis. The microscopic examination of the masses situated on the base of the skull showed that they contained absolutely no nervous elements. Rudiments of the pituitary body were visible. In the eyes the lenses were absent, as also the fibrous and ganglionic layers of the retinæ, neither was there any corpus ciliare or iris in either. In one of the eyes there was coloboma of the choroid and retina. The author considers that all this series of abnormalities is due to a primary enfeeblement of the formative energy, and not to special mechanical or pathological causes. He believes that this view is supported by the fact that the different abnormalities seem to have developed independently of one another during a fairly extensive period of time.

Taruffi (VI.) describes a case of agenosoma, in which the fœtus had an enormously distended abdomen, which contained a much dilated urinary bladder, which was unconnected with any urethra. There were no traces of spleen, pancreas, suprarenal capsules, prostate, or genitalia.

Ahleld (VII.), in a paper on certain malformations due to amniotic adhesions, states his belief that still, granulating flesh wounds met with in the fœtus at the time of birth (an example of which will be found in a paper by Priestley in *Trans. Obst. Soc.*, 1859, p. 60), are due to the tearing away of amniotic adhesions, which have taken place in the later part of pregnancy.

Taruffi (VIII.), with this, the eighth volume, brings to a close his monumental work *Storia della Teratologia*. In this place it is only necessary to state that this volume deals with defects of the ovum, macrostomia, &c., and contains an appendix, in which are given a number of cases relating to subjects dealt with in earlier volumes, which have appeared since their publication.

Ballantyne (IX.), in a paper on the Fœtus Amorphus, sums up as follows :—1. The fœtus amorphus mylacephalus is always the product of a plural conception (twin or triplet). 2. The co-twin is usually normal, and is almost always born first; with one doubtful exception, it was always of the same sex as the monster (when the latter possessed genital organs). 3. Very few general conclusions can be drawn as to the clinical details of these cases, but it would seem that the pregnancy usually terminates prematurely. 4. The mylacephalus usually forms a more or less rounded skin-covered mass, with the external indications of one or more deformed limbs. 5. The anterior surface is usually irregular, and gives attachment to the umbilical cord : a coil of intestines often projects into the root of the latter. The upper end sometimes carries hairs, and the lower has usually the rudiments of lower limbs hanging from it. 6. The most constant viscera are some coils of intestine, one or both kidneys, and the bladder. In no specimen was a trace of the heart found. The greater part of the fœtus is composed of œdematous connective tissue and fat. 7. The skeleton usually consists of a more or less defective spinal column, of the bones of one or more limbs, and occasionally of some of those belonging to the thorax and pelvis. 8. The placenta is probably always single, or at least fused, and the cord of the monster usually contains only one artery and one vein. (The writer may perhaps be permitted here to call the attention of those interested in the subject of Teratology to the papers and abstracts appearing quarterly in the Journal *Teratologia*, edited by the author of the last-mentioned paper, and to wish his endeavour all success.)

VASCULAR SYSTEM.—Finet (X.) describes a case of patent septum ventriculorum, where the aorta was placed immediately above the incomplete septum, thus receiving blood from both ventricles; the infundibulum of the pulmonary artery was much constricted, and there was a left superior vena cava.

Stoven (XI.) describes a case of dextrocardia in the living subject. (As to the rarity of the condition, it is noted that only two instances were met with amongst 20,000 German recruits.) The cardiac dulness was transposed to the right side, and the physical examination seemed also to show that the lung of that side had the incisura and processus linguiformis properly belonging to the left. The convexity of the dorsal portion of the vertebral column was turned to the left, from which (if that explanation has any real foundation) it may be supposed that the aorta was also transposed. The circumference of the left side of the chest was from 0·5 to 1·0 cm. greater than that of the right. The subject was not left-handed.

Arnold (XII.) gives a description of various cases in which diverticula of one or other chamber of the heart were observed.

Pangratz (XIII.) describes a case, with full details of the literature, doubling of the superior or inferior cavæ. The exact significance of the different conditions is also discussed.

TRUNK.—Brentano (XIV.) narrates a case of imperforate œsophagus, in which the upper portion terminated in a cul-de-sac extending as low as the cardia. The lower segment opened into the trachea.

Launay (XV.) gives a full account of the dissection of a case in which there was a complete transposition of the stomach, duodenum, biliary passages, pancreas, and spleen—that is, of the organs of the anterior and posterior mesogastria; the remaining organs of the abdomen and thorax occupying their normal situations.

Strube (XVI.), in a lengthy paper, gives a full account of the congenital alterations in position, form, and connections of the kidneys, with a list of papers connected with the subject.

Dionne (XVII.) adds two cases to list of supernumerary breasts: 1. In right axilla. 2. Two and a half inches to the right of the right breast. Secretion of milk seems to have taken place only in the normal glands. In this section may be mentioned some fresh cases of musculus sternalis. Gilis (XVIII.) has two cases. 1. Double and asymmetrical. Both joined the tendon of the right sterno-mastoid muscle above, that of the right side arising from the fifth rib, and of left from the sixth. 2. Double and symmetrical. Both arose from the fifth rib of their respective sides, and passing upwards formed tendons which united into a fibrous arch which lay at the junction of the superior and middle third of the sternum. In neither case is there any mention of the nerve supply. The author considers that the muscle belongs to the superficial plane of muscles concerned with the connection of the upper extremity to the trunk and head (trapezius, sterno-cleido-mastoid and pectoralis major).

Lambert (XIX.). The external part of the sternal tendon of the sterno-mastoid divided into two bundles, internal and external, which gave rise to the abnormal muscles. The two internal bundles crossed in the middle line. At the level of the third left rib, of the second right space, and the fourth right rib, fibres from the pre-sternals united themselves with those of the pectoralis major.

Mermet (XX.) gives an interesting account of the valves occasionally met with on the inner surface of the prepuce. They are of rare occurrence, for the author found them only five times in 10,000 cases, specially examined for the condition. These valves are situated on the internal surface of the prepuce and generally near the limbus, and they are usually multiple. The opening is directed forwards when the prepuce is drawn back, and hence, forwards when it covers the glans. The free border of the valve is concave, and measures from 2 to 14 mm., and the depth is from 6 to 12 mm.

EXTREMITIES.—Ermano describes a case (XXI.) of intra-uterine luxation of the humerus, with numerous references to the literature of the subject. He concludes that (1) a luxation of the humerus, congenital in its nature and intra-uterine in its origin, may certainly exist, but that its cause is at present uncertain. He thinks that the view which attributes this malformation to the pressure of the uterus on a fœtus surrounded by too small a quantity of liquor amnii may correctly explain the condition. (2) The varieties of this congenital luxation which may exist are (*a*) subcoracoid, (*b*) subspinous, (*c*) subacromial. (3) Many of the cases described as congenital luxations of the humerus do not really belong to the period of intra-uterine life.

In a lengthy paper entitled "Hand und Fuss," (XXII.) K v.Bardele-

ben sums up the literature which has appeared respecting the question of the existence of the remains of additional digits (præ-pollex and hallux and postminimus) in the human hand and foot. The author touches upon the subject of polydactyly, to which he proposes to return at greater length on a subsequent occasion.

A case of hereditary polydactyly is contributed by Delamare (XXIII.). It existed in three members of a family, viz., grandmother, daughter, and granddaughter. The first-named possessed a supernumerary digit on each hand and foot. Out of eight children whom she bore, there were four daughters, of whom three had six fingers and six toes on both hands and feet respectively, and the fourth, with the normal number of digits on each hand, had an additional toe on each foot. Of the three first-mentioned daughters only one grew up and married, bearing three children; of these, a boy had six digits on each hand and foot, and a girl had supernumerary fingers and toes also. In the cases of the grandmother and mother, the sixth digit, which articulated with the fifth metacarpal, was immovable, possessed a skeleton, and was in rank with the other digits. The supernumerary fingers and toes of the little girl had no skeleton, and were attached to the hands and feet by constricted pedicles.

Thilenius (XXIV.) gives the following list of supernumerary elements met with by him in an examination of 113 hands of human embryos from the second to the commencement of the fourth month. I. Dorsum Manus. 1. Naviculare bipartitum (radial and ulnar), two elements of nearly equal size, separated in a dorso-palmar direction. This condition was observed in four cases, in all of which there was also an os centrale. 2. Triquetrum bipartitum (radial and ulnar), separated as the first-mentioned bone; two cases. 3. Centrale, visible in all the hands. 4. Epilunatum, lying between os magnum and semilunar; four cases. 5. Epipyramis, lying between unciform, cuneiform and semilunar; four cases. 6. Trapezoides secundarium, lying between trapezium, trapezoid, and the second metacarpal; two cases. 7. Parastyloid, lying between trapezoid, the second metacarpal, and the styloid process of the third metacarpal, but volar to the latter; thirty-three cases. 8. Styloid (styloid process of the third metacarpal) in forty hands was either isolated or showed clear evidence of union; in the remainder it was present as a process of the same kind as that met with in the adult manus. 9. Metastyloid, lying proximally and somewhat volar to the styloid and between it, the os magnum and trapezoid; nine cases. 10. Capitatum secundarium (corresponding to the radially lying styloid), ulnar to the os magnum and between it, the unciform and the third and fourth metacarpal bones; met with in seventeen hands. II. Vola Manus. 11. Hypolunatum, between semilunar, scaphoid and os magnum; sixteen cases. 12. Os hamuli proprium (hamulus ossis hamati) was found in seven hands as an originally separated element. 13. Præ-trapezium, lying in front of the trapezium; four cases.

HEAD.—Manouvrier (XXV.), in a paper on the nasal bones, mentions some unusual varieties. Complete absences of these bones is rare, but the author has seen a case in which their place was taken by the

frontal: the skull in which this was observed was remarkable for the numerous abnormalities by arrest of development which the bones of the face and some of those of the base of the skull presented. Absence, or more frequently a diminution in size, of the nasal bones, their place being entirely or partially occupied by the nasal processes of the superior maxillæ, is a more frequent abnormality. The author has collected eight cases of this condition, forming a complete series, in which all the stages could be observed from that of complete absence to that of a simple arrest of development of the upper portion.

Guibert (XXVI.), in a study of a case of encephalocele, states that a histological examination of the ectopic portion shows that it belonged to the brain, but that its structure had remained embryonic. From the comparison of numerous cases the author concludes that the causes of encephalocele are probably numerous. The most frequent causes ought certainly to be referred to the commencement of development (lesions affecting the cerebral vesicles themselves, or due to amniotic bands and adhesions). The cystic transformation of primitively solid encephaloceles follows upon regressive processes analogous to those which take place in connection with an old cerebral hæmorrhage. To distinguish these tumours from ventricular hydrencephaloceles, they may be described as cystencephaloceles.

Duplicity.—A paper by Wiedemann (XXVII.) gives a lengthy account of the history of the various opinions concerning the origin of double monstrosity, in which, however, there are some notable omissions, Cleland's important communications on that subject having been missed. In summing up the evidence, the author, whilst refusing to commit himself to any definite opinion, seems rather to lean to the view that the fusion theory has more to recommend it than has generally been allowed in late years.

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Notices of New Books.

On the Development and Structure of the Whale: Part I. On the Development of the Dolphin. By GUSTAV GULDBERG, M.D., and FRIDTJOF NANSEN, Ph.D. Bergen: John Greig, 1894.

THIS monograph is chiefly based on material belonging to the Bergen Museum. The specimens examined were embryos of *Lagenorhynchus acutus*, *L. albirostris*, *Orca gladiator*, and *Phocœna communis*. After a historical review of the literature of the subject, the authors describe the characters of the specimens. They have had the opportunity of examining the placenta in various stages of development, when only incipient villi are present on the chorion, to a much more advanced stage. The villi do not assume their definite shape until the embryo has attained about one-tenth the length of the animal at birth. From the examination of small embryos of the common porpoise, 7 mm. and 17 mm. long, Dr Guldberg has seen a pair of processes projecting from the surface of the body on a level with the genital tubercle, which he regards as rudimentary hind-limbs. They are seen while the visceral clefts are distinct and paddle-like in shape, and scarcely half the size of the anterior limbs. They soon undergo retrogressive changes, and disappear when the cetacean characters of the embryo show themselves and the mammary organ arises.

The Anatomy of the Nasal Cavity and its Accessory Sinuses, an Atlas for Practitioners and Students. By Dr A. ONODI. Translated from the second edition by Dr ST CLAIR THOMPSON. London: H. K. Lewis. 1895.

THIS Atlas consists of sixteen small quarto plates, each containing a single figure, selected from a number of sections through the nasal cavities, which the author had prepared to show the topographical relations of this region. The preparations have been reproduced by photography, so that the relations of the parts have been faithfully rendered. The plates are preceded by a brief introduction descriptive of the nasal cavities with their communications. The description is sufficient for the purposes of the practitioner, for whom the Atlas is doubtless primarily intended. The figures are well executed, and make quite clear the arrangement of the bones and soft structures related to them.

Distribucion Geografica del indice Cefalico en España. By FEDERICO OLORIZ. Madrid, 1894.

DR OLORIZ has conducted an elaborate inquiry into the cephalic index of the Spanish people. He has measured the head in as many as 8368 adults, and has recorded his results in a volume of 292 pages, with numerous tables and two maps of Spain illustrating the geographical distribution of the cephalic index. The mean index for the population of the whole country is 78·18, *i.e.* mesaticephalic. In the different provinces and districts there are variations in the amount of this index. In only two localities does the mean index fall as low as from 74 to 75—viz., at Villena in Alicante and Yecla in Murcia. In Alicante generally, Castellon and Valencia on the eastern seaboard, the mean is between 76 and 77; in the Balearic islands and in the inland provinces of Saragossa, Valladolid, Zamora, Huesca, Burgos, Leon, and southwards at Cordoba, Jaen, and Granada, the mean index is between 77 and 78. In Murcia generally, Albacete, Cuenca, Ciudad Real, Seville, Badajoz, Caceres, Salamanca, Navarre, Lerida, Barcelona, Gerona, Bilbao, Orense and Corunna, the mean index is between 78 and 79. In Santander, Alava, Toledo, Cadiz, Malaga, and Huelva, the index is from 79 to 80, whilst in Oviedo and Lugo the mean index is above 80. It follows, therefore, that the most brachycephalic people in Spain are on the northern and southern seaboards, and at Toledo in the centre of the peninsula. The people whose heads approach most closely to the dolichocephalic standard are on the eastern coast; and the intermediate indices stretch across the country from the Pyrenees to the Portuguese frontier, and from Granada and Almeria in the south to Bilbao on the Bay of Biscay.

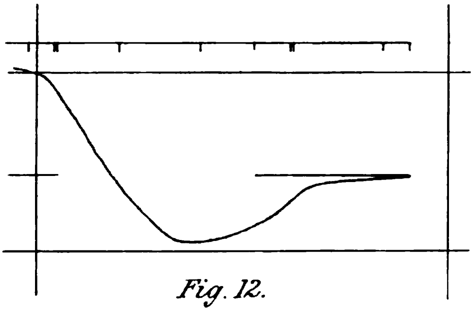


Fig. 12.

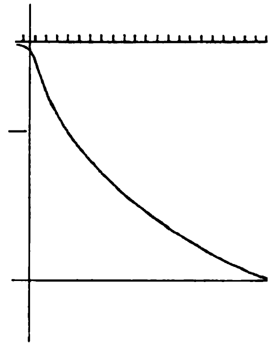
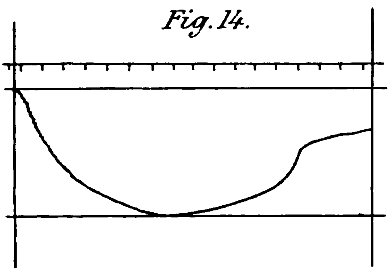


Fig. 14.



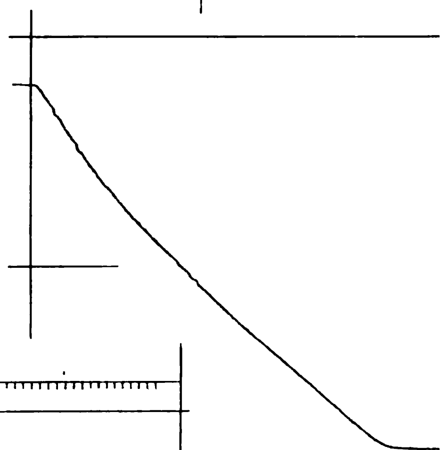
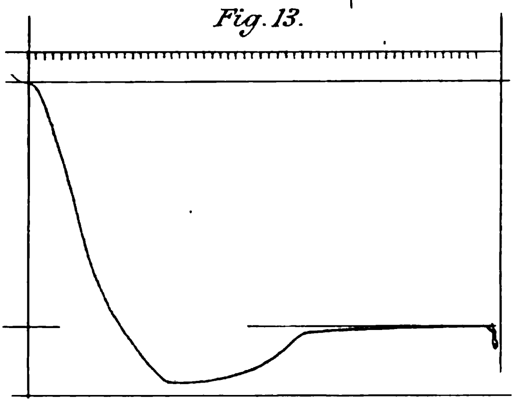


Fig. 13.



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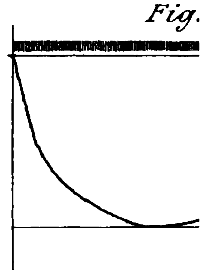


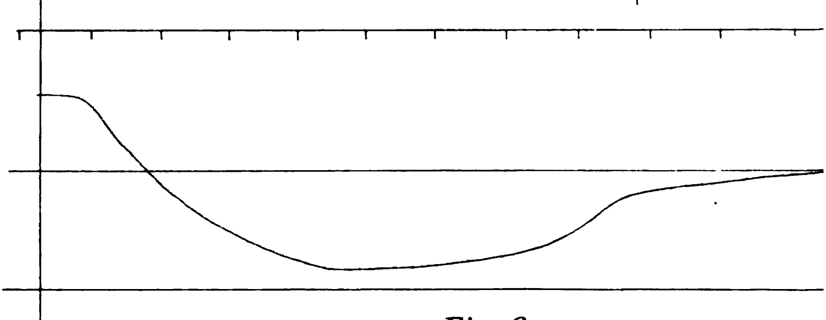
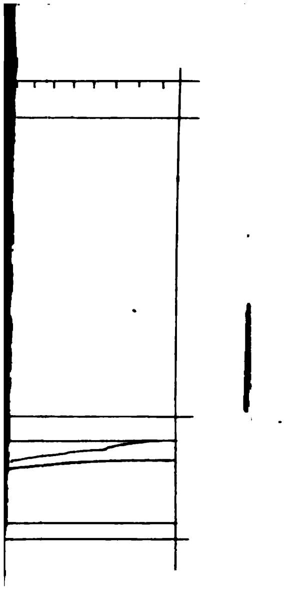
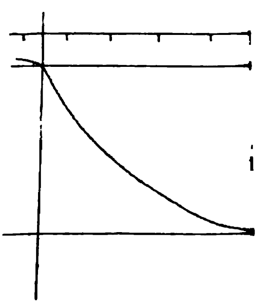
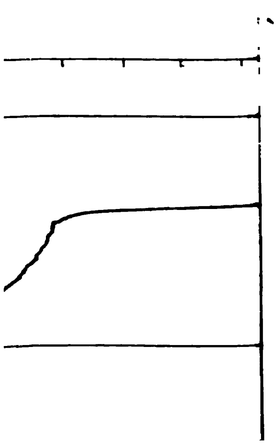


Fig. 9.







Journal of Anatomy and Physiology.

ON THE ANALYSIS OF VOLUNTARY MUSCULAR MOVEMENTS BY CERTAIN NEW INSTRUMENTS.[1]

By WILLIAM R. JACK, M.D., B.Sc., Glasgow.

(From the Physiological Laboratory of the University of Glasgow.)

THE object of this investigation was to determine the greatest speed of which the voluntary muscular movements were capable, and how far the speed was influenced by age and education. It was decided to limit the research to a study of the movements of the fingers, as being the easiest parts to examine of the muscular system. The writer has to acknowledge his indebtedness to Professor M'Kendrick for much valuable assistance and advice.

The first instrument used was one devised by Professor M'Kendrick, and figured at page 78 of his *Life in Motion* (first edition, 1892). It consisted essentially in a tuning-fork, carrying a smoked microscopic slide, and set in motion by a bichromate cell. With all its loads, the fork made 117 double vibrations per second, as determined by the chronograph. Lines drawn upon the attached slide, perpendicular to the plane of vibration, were therefore thrown into waves, each of which represented the space passed over in $\frac{1''}{117}$. The different movements investigated in this way were the following: (1) The greatest velocity attainable by the single contraction of one finger to which a finely-pointed needle was affixed. (2) The greatest velocity attainable by the single contraction of the fingers in combined

[1] The complete paper, of which this is an abstract, with illustrations, has been communicated to the Royal Society of London, who defrayed the expenses of the research.

action. For this purpose the needle was fixed in a penholder and held like a pen, care being taken to see that there was no movement of the wrist, but only of the fingers. (3) The greatest velocity attainable in ordinary writing. In this way, therefore, the velocities of a series of movements increasing in complexity could be compared. The velocity of curves, and of curvilinear figures, was also compared with that of straight lines.

Twenty-three normal and two pathological cases were examined. The normal cases were divided into three classes: those of special manual education (musicians); those of average manual education (the ordinary educated classes); and those of inferior manual education (working-men), in whom the hands were accustomed only to coarse movements, and the fingers had no special training. Of the first class there were five examples; of the second and of the third, nine. The ages varied from eighteen to sixty-two.

While the tracings were being made, the hand rested on a little table at the height of the recording slide. It was found that the velocity of the more complicated movements could be increased to some extent by practice. Only a few preliminary tracings, to accustom the hand to the instrument, were therefore allowed to each subject, in order that all might be as much as possible on the same footing. Full details of the velocities attained in each case, and figures of the apparatus used, are given in the original essay. In this abstract only a statement of the results attained will be made.

It is not contended that the figures here given represent the absolute velocities of the movements made, for the retarding influence of friction on the slide has to be allowed for, and the increase in the space travelled over, through the extension of the needle beyond the end of the fingers. But as all the subjects were under the same conditions, a comparative estimate of the velocities may be arrived at.

Beginning with the influence of training upon the velocity of the movements, the pen-movement was first studied, and the rate at which a distance of 3 cm. in the middle of the slide was traversed was taken as the standard of comparison. Unfortunately, no tracings of this movement were taken from musicians; but on comparing the average of the tracings derived from those

of average and those of inferior manual education, the following conclusions were arrived at:—

1. That in those of inferior manual education (whose two hands were both untrained) the velocity is equal in both hands ($\frac{3\cdot4''}{117}$ for the right and $\frac{3\cdot5''}{117}$ for the left hand).

2. That in those of average manual education, the velocity is greater in the right hand, which has been trained (as in writing), than in the left, which has not ($\frac{2\cdot9''}{117}$ for the right and $\frac{3\cdot6''}{117}$ for the left hand), an exception being found in the case of the author, both of whose hands have been pretty equally trained, in which case both had the same velocity ($\frac{3''}{117}$).

3. That the velocity is greater in the right hand of those of average education than in the right hand of those of inferior education.

4. That the velocity in the left hand (which has been little trained) of those of average education is practically identical with that in the left hand of those of inferior education.

The velocity of contraction of a single finger was next examined, with the following results:—

1. That the velocity is equal, or nearly so ($\frac{2''}{117}$), in the first and second fingers, and is greater than that in the third and fourth, which have also a nearly equal velocity. This may be due to the special arrangement of the tendon of the extensor communis digitorum for the third finger, and for the fourth to the awkward position in which it was placed.

2. That the velocity of each finger is practically identical for the two hands.

3. That the velocity of the finger-movements is not appreciably affected by manual training. The most rapid single contraction of the fingers of a trained pianist is very slightly, or not at all, faster than that of a working-man.

4. That the velocity of movements of flexion is, on the average, slightly greater than that of movements of extension, although in two of the eight cases examined the velocities were identical.

5. That the velocity of the finger-movements, as a whole, is greater than that of the pen-movements.

In examining the more complicated movements of writing, it was found—

1. That the average velocity is practically the same in musicians and in those of average education, their training in this regard being nearly equal.

2. That the velocity in the untrained working-classes is much less than in the two former.

3. That the velocity in all classes is much less than in the pen-movements.

4. That the curved parts of letters and figures are more slowly formed than the rectilinear parts, and that the velocity of a curve varies, roughly speaking, with the radius of curvature.

The difference, then, between education and the want of it is greatest in writing, less in pen-movements, and scarcely noticeable in the simple finger-movement; and the average velocity for all classes is least in writing, much greater in pen-movements, and greatest in finger-movements. The velocity therefore diminishes, and the difference between the various classes increases, as the movements become more complex. The more nearly they approach to a simple muscular contraction, the less is the difference noticeable, though it would doubtless be found that the musician is able to repeat a series of simple muscular contractions much more rapidly than one with untrained fingers.

The influence of age upon the velocity of the movements was next investigated, and it was found, with regard to writing,—

1. That the velocity of the movements of writing becomes slower with advancing age.

2. That it is greatest between the ages of twenty and twenty-nine, and decreases with every decade thereafter.

3. That this decrease is greater in the uneducated than in the educated.

With regard to pen-movements, it was found—

1. That the decrease in velocity is less marked than in the case of writing.

2. That the velocity is greatest between the ages of twenty and twenty-nine.

3. That the difference in the rate of decrease, between the educated and uneducated classes, is not so marked as in the case of writing.

With regard to finger-movements, it was found that they retained nearly the same velocity for all classes between the ages of twenty and fifty; and that in the one case of a man over that age (a labourer æt. sixty-two) there was a decided decrease.

In the two pathological cases investigated—one of lateral sclerosis in a man of forty-one; and one of tremor of the hands, following upon syphilis, in a man of fifty—similar results were obtained; for the complex movements of writing were most seriously retarded, the pen-movements less, and the finger-movements least of all.

It appears, then, that as a movement increases in complexity, and involves in its performance the associated action of a greater number of muscles, its velocity diminishes, and the influence of education becomes more distinctly manifest; and as complex movements require a longer education for their rapid performance, they appear to become sooner defective than the simpler movements. For it is in writing that the retarding effect of age is most apparent, while it is least in the finger-movement.

In the second part of the investigation, it was desired to obtain tracings from a larger series of contractions than could be registered upon a microscopic slide. For this purpose new instruments were required, and, owing to the long delay in making these, but few experiments have been recorded. The instrument finally adopted consisted in a long steel bar, held firmly in an iron clip, and carrying in a clamp attached to one end a smoked glass plate 6 inches square. It was set in motion by an electro-magnet, through which passed the current from a storage battery, and, as determined by the chronograph, it made fifty-four double vibrations per second. At Professor M'Kendrick's suggestion, it was determined rather to investigate with this instrument the phenomena of fatigue, a purpose for which he thought it very suitable. With this object, Mosso's ergograph was adapted to the instrument, the recording part of which could be pulled on rails slowly away from under the registering lever, which worked up and down with the movement of the weighted finger. Thus a series of contractions and relaxations, divided by the oscillations of the bar into fifty-fourths of a second, was registered on each plate. The plate could be

taken out and a new one substituted beneath the lever without stopping the movement of the finger. A key was interposed in the circuit to shut off the current while the plates were being changed.

Four normal and two pathological cases were investigated, series of tracings being taken with a ½-kilo, a 1-kilo, and a 2-kilo weight. They show in a very striking manner the diminution in the height of the contraction, and the coincident diminution in its velocity, due to fatigue. The measurements which were taken of the rates of velocity at different parts of the tracings afford somewhat varying results, and the number of cases is too few for any definite conclusions to be drawn from them. But it would appear that, while the diminution is gradual and uniform in the case of small weights, in that of larger weights it occurs, as a rule, more rapidly, and that the rate of diminution does not remain the same throughout the tracing.

NOTE ON THE MINUTE STRUCTURE OF THE RETICULUM IN THE CAT'S SPLEEN. By E. W. CARLIER, M.D., *Physiological Laboratory, University of Edinburgh.*

(Read before the Scottish Microscopical Society, 17th May 1895.)

Method.—The animal being deeply anæsthetised, the thorax should be rapidly opened, the apex of the heart removed, and a cannula passed through the left ventricle into the aorta and tied there. This cannula should be attached by an elastic tube to a jar placed 8 feet above the table, and filled with normal saline solution heated to the body temperature. About a litre of this solution is allowed to flow through the blood-vessels of the animal, to wash out the blood. When the salt solution begins to run clear, about one and a half litres of strong picro-corrosive solution (Mann's formula [1]), previously heated to the temperature of the body, is substituted for the salt solution, and allowed to flow through the vessels. In this way the fixing agent is enabled to come into intimate contact with every part of the tissue; for if not too hot, it penetrates into even the smallest capillaries, and fixes every cell in its normal condition.

When about a litre of the fixing fluid has been allowed to flow, the animal becomes perfectly rigid, and the tissues appear of a pale yellow tint. Five or ten minutes after the injection is completed the tissues are removed and placed—entire if they are small, or cut in pieces if large—in a considerable quantity of the same solution, heated to the body temperature, and allowed to remain for twelve hours. They are then washed in several changes of 50 per cent. alcohol, taken through the alcohol series into chloroform, and finally imbedded in paraffin in the usual way.

After imbedding in paraffin, the tissues were cut with a rocking microtome, the sections being 1 to 2 μ and in the case of a few 5 μ in thickness. When cut, the sections were fixed

[1] G. Mann, *Proc. Scot. Micro. Soc.*, 1893–94, p. 154, see Appendix A.

to albuminised slides (Mann's method [1]) after being spread on warm water, dried at a temperature of 30° C., passed through xylol into iodine in iodide of potassium solution to remove all trace of corrosive sublimate, and after removal of the iodine, were stained either in Ehrlich's original tri-acid or in Mann's methyl-blue eosine mixture (long method [2]), and finally, after clearing in xylol or resinified turpentine, mounted in balsam.

The preparations were examined with a Leitz $\frac{1}{12}$ oil immersion objective and No. 12 compensating eyepiece.

The stream of salt solution having been allowed to flow freely through the tissues, most of the loose corpuscles, with which the splenic pulp is normally filled, were washed away, and the structure of the reticulum plainly shown.

Splenic Reticulum.—The splenic reticulum, instead of being a network of branched endothelial cells, united by their processes, as usually described, was found to consist of numerous fine branching strands of connective tissue, springing from and continuous with the fibres of the trabeculæ, walls of the blood-vessels, and splenic capsule. The fibres vary in size and cross each other in every direction, numerous anastomoses occurring between them.

Here and there the strands are clasped by connective-tissue cells, the nuclei of which are characteristic; and as some of these cells were partly detached, there could be no doubt whatever concerning their identity. Besides, when stained in methyl blue eosine by Mann's rapid method,[3] with the subsequent addition of 1 % methyl blue, for three to five minutes, the fibres became intensely blue; this reaction is characteristic of connective tissue, epithelial cells staining red. My specimens therefore confirm fully the observations of Bannwarth.[4]

The splenic reticulum must therefore be looked upon as identical with that of lymph glands, which consists of branching and anastomosing connective-tissue fibres with clasping cells, as pointed out by Ellenberger, Ranvier, myself, and others.[5]

1 G. Mann, *Anat. Anzeig. Jahrg.*, viii. (1893), p. 442.
2 G. Mann. See Appendix B.
3 G. Mann. See Appendix C.
4 Bannwarth, *Archiv. f. Mikro. Anat.*, xxxviii. p. 345.
5 *Journ. Anat. and Physiol.*, xxvii. p. 354.

Notwithstanding the fact that the trabeculæ from which this reticulum springs are almost entirely composed of non-striped muscle fibres, mingled with a certain amount only of fibrous tissue, practically no muscle fibres are found entering into its formation. Now and again, in the neighbourhood of the trabeculæ, an isolated muscle fibre may be found imbedded in a somewhat thicker strand of the reticulum, but even this is rare; and in no case are the muscle fibres continued in it for any distance.

Splenic Ellipsoids.—These bodies consist of a loose network of collagenous fibres, directly continuous, on the one hand, with the enclosed vessel wall, and on the other, with the strands of the pulp reticulum in their immediate neighbourhood. The arrangement of these fibres is quite irregular; they are more closely packed than the fibres of the reticulum, and bear the same relation to it that a piece of compressed sponge does to an uncompressed piece.

Amongst the fibres are numerous nuclei of connective-tissue type, enclosed in small cell plates wedged in between the fibres. They have no regular arrangement, beyond being, like the fibres themselves, disposed more or less around the vessel walls.

The nuclei of the ellipsoids are not larger than those of the clasping cells of the pulp, but are often of irregular shape and somewhat poor in chromatin, which is distributed beneath the nuclear envelope in the form of granules of varying size united by very fine threads.

The nucleolus, which is usually single and contains a single endonucleolus, is enclosed by a sphere of chromatin, from which fine threads pass to form a junction with that beneath the envelope.

The endothelial lining of the capillaries within the ellipsoids is described by Bannwarth as greatly swollen and peculiar; but as his preparations were hardened by immersion in Müller's fluid, his observations require confirmation. In my preparations, in which these cells—which were certainly fixed whilst still living — present a remarkable appearance, they are thick, elongated, spindle-shaped cells, longitudinally arranged in the capillary; their nuclei are short, oval, and scarcely at all flattened; the protoplasm stains deep wine-red with tri-acid, and the cell

has an almost rounded outline in cross section. These cells project boldly into the lumen of the capillary, converting it into a stellate channel; they closely resemble both in shape and arrangement the muscle fibres that lie inside the basement membrane of sweat glands, and present none of the usual characters of endothelial cells. Indeed, were they not within blood-vessels they would scarcely be believed to be endothelial.

Here and there amongst the fibres, where the meshes are a little wider, isolated red blood corpuscles may be seen, just as in the pulp itself; which is an additional support to the theory that these ellipsoids are really part of the splenic reticulum especially modified. These blood corpuscles are much too irregularly placed for it to be possible that they should be in any kind of capillary, however tortuous; they merely lie between the fibres, so that the whole ellipsoid, like the pulp, has blood circulating through it, though no doubt this is rather of the nature of a percolation than of a circulation in the usual sense of that term; for, owing to the closeness with which the fibres are arranged, it must be somewhat difficult for a corpuscle, when once entangled within its meshes, to again become free. Leucocytes may now and again be seen entangled, but they are much less numerous than the red cells.

The fibres of the ellipsoid are directly continuous with the strands of the pulp reticulum, without the interposition of a vascular sinus described by Müller as surrounding the ellipsoids in birds, and by Whiting[1] those of the cat. In the neighbourhood of these bodies—but not in connection with them—splenic sinuses are certainly sometimes found, but they are quite different from the channels described by these authors, of the existence of which I can see no evidence whatever. In this I agree with Bannwarth, who denies their existence in the cat and other mammals examined by him. Lastly, there appear to be no muscular fibres in the ellipsoids, and therefore they can exert no contractile force either to assist or retard the flow of the blood.

It is difficult to say whether or not any function should be assigned to these ellipsoids, but their position round the terminations of the arterioles, and the great thickening of the endo-

[1] Whiting, *Proc. Scot. Micro. Soc.*, 1892–93, p. 105.

thelial lining of the capillaries springing from these vessels within them, suggests that this part of the spleen may be subjected—either at every heart-beat, or during some period of its rhythmical contraction—to a strain that might be sufficient to rupture delicate capillaries if lying unsupported in the pulp; and that the ellipsoids may act as supporting structures to prevent such accident.

Splenic Sinuses.—Almost anywhere in the pulp splenic sinuses may arise as in the human spleen, but they are small and narrow. They are usually surrounded by a perforated wall of connective tissue composed of anastomosing strands of the reticulum, which are slightly condensed, and more regularly arranged than elsewhere in the pulp. Internal to this wall and applied to it are endothelial cells irregularly scattered at intervals; as the sinus becomes more defined these become more numerous, and finally produce a complete endothelial wall for the commencing vein, as usually described.

Summary.—1. The splenic reticulum consists of connective-tissue fibres with clasping cells, as in lymphatic glands.

2. The splenic ellipsoids are fibrous in nature, and may be considered as condensations of the reticulum around the terminations of the arterioles; they present no special blood sinus at their margin.

3. The splenic sinuses begin as spaces in the pulp, surrounded by a slight condensation of the reticulum, lined here and there by endothelial cells.

APPENDIX.

(A) *Mann's Fixing Solution.*

Martin Heidenhain's solution (12 grms. $HgCl_2$ in 100 cc. of 0·75 per cent. NaCl sol.),	100 cc.
Picric Acid,	1 grm.
Tannic Acid,	1 grm.

(The Tannic acid may be omitted.)

(B) *Mann's Long Method.*

1 per cent. Methyl-blue (Grübler), water soluble, and almost quite insoluble in Alc. absol.,	= 35 cc.

1 per cent. Eosine, water soluble (Grübler), . .	45 cc.
Aq. destill., ...	100 cc.

(1) Stain for 24 hours. (2) Remove superfluous stain with water. (3) Dehydrate with Alc. absol.

(4) Place slide in a glass vessel containing Alc. absol. 30 cc.
1 per cent. NaOH in Alc. absol., . . . 4 drops.

(5) Leave in this mixture till the dark blue section has become reddish (1-5 minutes).

(6) Wash off all traces of caustic soda with Absolute Alcohol.

(7) Place sections into a vessel with tap water; bluish-red clouds will be given off.

(8) When no more clouds are given off, transfer slide to a vessel containing water which has been acidulated with 2-3 drops of Acetic acid. Leave section in this water for 3 minutes to neutralise all traces of NaOH, to fix the Eosine and to deepen the colour of the Methyl-blue.

(9) Dehydrate with Alc. absol. and mount in Turpentine balsam.

(C) *Mann's Rapid Method.*

1 per cent. solution of Methyl-blue (Grübler), water soluble, ...	35 cc.
1 per cent. solution of Eosine, water soluble (Grübler),	45 cc.
Aq. destill., ...	100 cc.

(1) Stain sections in this from one to three hours.

(2) Wash thoroughly in tap water.

(3) Dehydrate, clear in turpentine or xylol, and mount in balsam.

ON THE PRESENCE OF SCALES IN THE INTEGUMENT OF *POLYODON FOLIUM*. By WALTER E. COLLINGE, F.Z.S., *Assistant Lecturer and Demonstrator in Zoology and Comparative Anatomy, Mason College, Birmingham.*

WHEN investigating the sensory organs in the region of the lateral sensory canal in *Polyodon folium*, I was interested in finding certain structures in the integument which resembled the early stages of scale formation as described and figured by Klaatsch,[1] Hofer,[2] Nickerson,[3] and other writers.

I would point out that the material I had was not the best for histological investigation, having been in alcohol for some years. The results obtained are, I think, worthy of noting, and it is to be hoped that others possessing better material will more thoroughly work out the subject.

In *Lepidosteus*, Nickerson describes the dermis as consisting of two layers, an outer spongy layer and an inner fibrous layer, the two not being definitely separated from one another. In certain parts of this spongy layer the cells increase in number, and in these regions a series of cells become differentiated, to which Klaatsch has given the name "Scleroblasten"; from these cells a thin calcareous sheet or scale-plate is secreted in the middle of the spongy dermis (fig. 1). The scale-plate continues to increase in size and thickness, enclosing within its substance numerous scleroblasts, and also increasing laterally. The scleroblasts are contained in cavities from which numerous canaliculi pass off. There is a tendency for the canaliculi to spread themselves out "in a plane parallel to the surface of the scale," so that the "material of the scale is divided into more or less regular lamellæ of calcareous matter, alternating with successive layers of cell cavities, and their connecting canaliculi." Of the

[1] *Morph. Jahrb.*, 1890, Bd. xvi.

[2] *Sitz. d. Gesellsch. f. Morph. u. Physiol.*, Munchen, 1890, Bd. vi. p. 103.

[3] *Bull. Mus. Comp. Zool.*, Harvard, U.S.A., 1893, vol. xxiv. pp. 115–139, plates i.–iv.

later stages which Nickerson has so carefully described and figured, it is unnecessary here to mention.

The integument of *Polyodon*, but for the presence of a series of scattered papilla-like sense-organs, is perfectly smooth, and

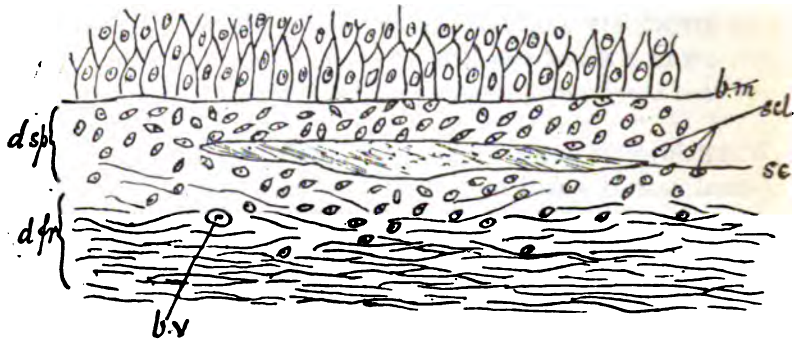


FIG. 1.—Longitudinal section through skin of young Lepidosteus, modified from Klaatsch and Nickerson:—*b.m*, basement membrane; *b.v*, blood-vessels; *cal. par.*, calcareous particles; *d.fr*, fibrous portion, and *d.sp*, spongy part of dermis; *sc*, scale-plate; *scl*, scleroblast.

there are no external signs of either scales or dermal spines; but when sections were made of the integument, a calcareous layer was met with in the dermis, replacing almost the spongy layer,

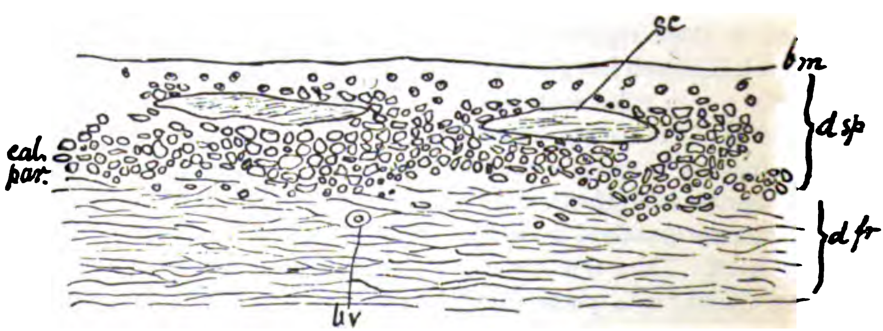


FIG. 2.—Longitudinal section through skin of *Polyodon folium*:—(Lettering as in Fig. 1).

and lying upon the fibrous layer. When examined under the microscope, the condition found was as follows:—

Beneath the epidermis was a thin spongy layer of dermis, covering a series of small loosely-arranged calcareous bodies,

some of which lay in the underlying fibrous dermal layer. Amongst these, at varying distances, were isolated irregular plate-like calcareous bodies (fig. 2), resembling very closely those found in the young Lepidostei. Below this layer the ordinary fibrous layer of dermis was present.

In *Polyodon*, the formation of the scale seems never to get beyond a stage common to the embryos of Ganoids and Teleosts, but has ceased somewhere about the stage I have referred to as figured by Nickerson in *Lepidosteus*, and Klaatsch in certain Teleostei.

Some years ago Traquair drew attention to the similarity of the imbricating V-shaped scales of the *Palæoniscidæ* and those of *Polyodon* on the caudal prolongation of the body. The presence of other scale-like bodies adds another point, and strengthens the relationship.

THE OBLIQUITY OF THE ARM OF THE FEMALE IN EXTENSION. THE RELATION OF THE FOREARM WITH THE UPPER ARM IN FLEXION. By H. PERCY POTTER, M.D., F.R.C.S.

To the careful observer it is evident that the forearm, when fully extended and supinated, bears to the upper arm a certain angle, and that this fact is more pronounced in the female than in the male sex.

In tall persons this obliquity is apparently more marked, since the arms of the angle are longer. By measurement it is found that there is a definite ratio or proportion of axial divergence in the lower, compared with the upper extremities. The width and conformation of the female pelvis necessitates convergence of the thighs inferiorly, and a corresponding divergence of the legs, in order that the equilibrium may be maintained. It is supposed that the obliquity of the forearm subserves a distinct mechanical advantage, in that prehension is facilitated, and during flexion, when the hand is brought towards the middle line of the body, defence is prompt, and nourishment can easily be conveyed to the mouth. But we shall presently try to show that there is no convergence of the hand in flexion towards the trunk.

Two methods have been employed to obtain accurate results of angularity, which check one another by cross corrections. We have used a narrow three-foot rule, hinged at its centre on the flat, having a disc, divided into degrees, attached firmly to one arm of the rule. When this is applied to the limb, the angle formed by the forearm is read off. Secondly, a plumb line is set carefully to the front and mid-line of the upper arm, the string touching the lesser tuberosity, and allowed to fall exactly in the centre of the elbow. It is observed that the plumb falls well within the centre of the wrist in supination—the palmaris longus tendon. The distance between the plumb line and the tendon is read off in inches and decimals. This number

divided by the length of the forearm and calculated from a Table of Natural Sines gives the degree of divergence from the vertical axis.

For many years it has been interesting to gauge the obliquity of the bare arms of female patients in hospital, and to compare this with the legs. In some extreme cases, with a length of forearm of 9 inches, the distance between the line and wrist centre is 3 inches, which gives a ratio of $\frac{3}{9} = \cdot 333$, which is the sine of $19 \cdot 5°$, this being the angle of deflection of the forearm from the plumb line, or an angle $160 \cdot 5°$ with the upper arm.

In the erect posture of the body with the arms to the side, the humerus inclines at its lower end inwards; when the forearm is semiprone this is inclined downwards and slightly outwards, thus correcting any inward inclination of the hand.

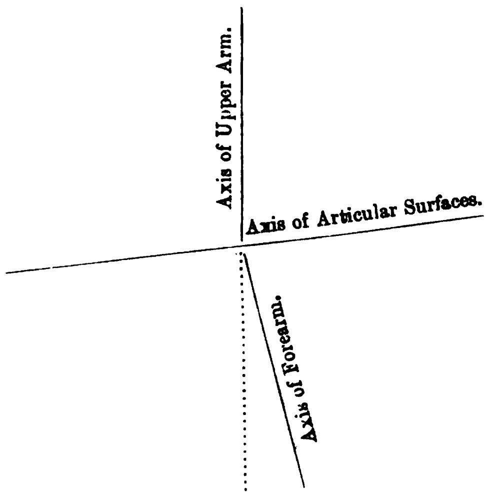
The most prominent part of the trochlea is the internal margin, which forms an angle with the horizontal of 150°. Rotation of the ulna in flexion would cause the forearm to be thrown towards the middle line of the body if it were not for the peculiar shape of the articular surfaces of the greater sigmoid cavity. It is commonly asserted that the degree of convergence of the forearm towards the trunk in flexion is proportionate to the obliquity outwards in extension, but I endeavour to show that there is a rectification or restitution of the forearm, in exactly the same axis as that of the humerus; in other words, when the forearm is firmly bent, it lies in the *same* plane as the upper arm, and immediately in front of it. Therefore there is no inclination inwards. This is accounted for by the fact that the conoidal surfaces of the greater sigmoid cavity adapt themselves to the trochlea, and that the axis of rotation of the ulna is not at right angles to the ulnar shaft, but if this axis be extended outwards it will form an acute angle with the ulna. The same applies to the axis of the trochlear surface with the humerus, *i.e.*, if the axis of the trochlea be extended outwards it will make an acute angle with the humerus, which acute angle is practically equal to the acute angle made by the axis of the great sigmoid cavity and the ulna.

These facts can be demonstrated with the bones in position,

or perhaps more conspicuously by the aid of the following diagram.

The paper, if folded in a line corresponding to the axis of cone surfaces of the ulna and trochlea, will cause the line of the forearm to lie directly over the upper arm.

In cases of genu valgum, surprise is often expressed by the student when the surgeon, on flexing the knee, causes the deformity to disappear; the leg in this case lies directly behind the thigh in the same vertical plane, and is due to deficiency of that prominence of the internal condyle behind, which is so



apparent on the inferior aspect. Thus, a patient under treatment with knock-knee shows 9½ inches of separation of the internal malleoli with the femora vertical. This deviation is entirely corrected upon flexion of the leg.

Having stated generally the results of observations, it is necessary to revert to obliquity in extension, and briefly to record the measurements obtained.

In 90 cases, taken indiscriminately, of deviation of female arms, the angle of obliquity of the forearm with the upper arm is 167·35°.

In 95 cases in the male, the angle is 173·17°.

Many measurements have been taken of the degree of obliquity of the leg, but, beyond stating that there is always a corresponding or rather proportionate angularity of the forearm in the same subject, these do not concern the object of these remarks.

I have thus endeavoured to show that the forearm of the female is markedly more oblique that that of the male, and there is no deviation inwards of the forearm during flexion in the upper extremity of either sex.

For being permitted to take measurements at the Royal College of Surgeons, my best thanks are due to Professor Stewart the Conservator.

THE MORBID ANATOMY OF THE BONES IN CHRONIC GLANDERS IN THE HUMAN SUBJECT. By Gordon Sharp, M.B. Edin.

So few opportunities present themselves of studying the pathological conditions in bone in glanders, as it affects Man, that every case is interesting. For this reason I have made a naked-eye and microscopic examination of an upper jaw bone removed during life from a man the subject of chronic glanders.

The literature is scanty, most books merely mentioning the fact that the bones, especially of the face, may undergo changes of an indefinite kind, and be the seat of abscesses.

Naked-eye Examination of Upper Jaw.—The disease had run a course of eight months at the time of removal of the bone. The teeth are noticeably sound, and firm in their sockets. The soft parts of the hard palate have sloughed away, and the underlying periosteum is swollen, dark in colour, and in some parts black, while in other parts it has sloughed away, leaving the underlying bone bare, thin, and soft to the touch. In the meatuses black sloughs are seen; and when these are removed, the bone underneath is found to be thin and soft (not brittle), and in one part there is a large oval opening extending from the meatuses to the maxillary antrum. As the disease first manifested itself in the nostril of this side, this opening may correspond to the starting-point of the disease. On the facial surface of the bone there is evidence of extensive inflammatory mischief, for the whole periosteum is injected, and shows in every part points of redness, except where the space is occupied by black sloughs. The anterior wall of the antrum gave way in part on removal of the bone. The antrum itself was filled by an intensely foul abscess of a dark yellow colour, stained here and there with blood. Judging by the naked-eye appearances, the pathological condition present in chronic glanders would appear to be a slowly acting necrosis attacking chiefly the periosteum; hence we do not find large white areas of dead bone, such as are to be found in the acute infective diseases

Microscopic Appearances.—A portion of bone from the facial surface of the upper jaw was decalcified by being digested for a day or two in the dilute hydrochloric acid of the British Pharmacopœia, then well washed in cold water, next digested for a few minutes in a half per cent. solution of caustic soda, and finally washed in cold water for 24 hours. The specimen was next dried by pressing between the folds of a cotton cloth, frozen, and sections cut so as to show the structure transversely, stained with picrocarmine solution, and mounted in Farrant's solution, and examined both by low and high powers. The periosteum is enormously thickened by infiltration of small round cells, by the presence of hæmorrhages, and by growth of fibrous tissue. Here and there the periosteum is awanting, and one can trace the agency by which its removal has been effected, in the shape of giant cells, with their attendant small round cells. On close examination these large multi-nucleated cell systems are seen to have taken up a position between the periosteum and the bone, and have gradually but effectively forced these structures apart, and so caused the death of both (periosteum and bone). The process is a slow one, for in a considerable area of bone one finds only a small proportion of periosteum awanting. Further, the process, instead of being largely one of disintegration, as one finds in tubercular and other conditions, is chiefly mechanical.

Passing on from the periosteum to the bone, the giant cells are seen to have made their way into the centre of the bone, and are breaking it up simply by pushing aside the bone tissue. Scattered throughout, one sees a small amount of new fibrous tissue, irregular in growth. The result of this pushing aside of the soft parts of the bone by giant cell systems is that empty spaces with smooth edges, and round, oval, and linear in shape, are to be seen. Other spaces are filled with blood, while others again contain small nucleated cells. The extension of these giant cell systems into the interior of the bone is comparatively small, showing that glanders does not readily attack bony tissue.

The diagnosis of the disease was verified by staining some of the discharge from the nostrils with methylene blue, and finding the characteristic micro-organism, the *bacillus mallei.*

THE MORPHOLOGY OF THE OBLIQUE RADIO-ULNAR LIGAMENT. By EDWARD FAWCETT, M.B., C.M. Edin.,

Professor of Anatomy, University College, Bristol.

FOR some years past I have been suspicious of the nature of this ligament, but till quite recently have been unable to obtain complete proof that these suspicions were well founded: fortunately, during the last month, three specimens have come under my notice, which, to my mind, settle the point absolutely.

As is well known, the oblique radio-ulnar ligament stretches from the "tubercle" of the ulna to the upper end of the "anterior oblique line" of the shaft of the radius. But it does not retain undisputed possession of those bony points, because careful dissection reveals that in most cases it is covered in its whole extent by the coronoid head of the flexor longus pollicis muscle. This coronoid head, when present—and it usually is present—stretches between the "tubercle" of the ulna and the "anterior oblique line" of the shaft of the radius. Its bony attachments are therefore similar to those of the oblique radio-ulnar ligament on which it lies, and which it generally conceals. Both structures lie in close contact with the tendon of the biceps at its point of insertion into the "bicipital tuberosity," and the ligament seems to tie down that tendon. Several of the text-books state that this ligament is occasionally absent, and I am inclined to think that I should have been led to make the same observations in the three above-mentioned cases, had not experience put me on my guard, and warned me that careful dissection and preservation of all the structures attached to the coronoid process and the upper part of the radius were absolutely necessary; indeed, in the first case, my attention was attracted by the inability of the student dissecting the part to find the ligament in question. And why? Because he had reflected the coronoid head of the flexor longus pollicis, and had in this instance, unwittingly, also reflected the oblique ligament. For after looking in the usual place for the ligament, and finding it wanting, I noticed that the coronoid head of the flexor longus pollicis, which had been

turned up, was wholly tendinous as far as the upper end of the "anterior oblique line" of the radius, and that this tendon, when placed in its original position, occupied exactly the position the ligament does when present, and that having reached the upper end of the anterior oblique line, it became muscular, and the muscular fibres, the dissector told me, were directly continuous with those of the flexor longus pollicis which arise below the anterior oblique line, and I have no reason to doubt his word. Since then, as I have said before, I have seen two additional instances of this condition, and I have been able to confirm the suspicions cast on the first, viz., that the ligament and the muscle were one and the same thing. In this description of the coronoid head of the flexor longus pollicis, so far as it concerns its site of origin from that process, I know I am at variance with the text-books, which, so far as I know, one and all describe it as coming from the inner side of the coronoid process, and, moreover, as being occasional. I admit that such an origin is occasional, and at the same time assert that the head I have described as coming from the "tubercle" of the ulna, and therefore from the *outer* side of the coronoid process, is usual, for I have rarely found it absent. When we consider the flexor longus pollicis as a whole, from the morphological point of view, we find that it only exists as a separate muscle in man (Quain), and that in the rest of the primates it is always blended with the flexor profundus digitorum to a greater or lesser extent. If we trace the tendons of the flexor profundus digitorum to their muscular bellies, and those bellies to their highest attachment on the ulna, we find that the muscular fibres concerned with the tendons to the fifth, fourth, and third digits lie to the inner side of the coronoid process chiefly, that the muscular fibres to the tendon for the index finger arise from the outer side of the apex of the coronoid process. What is more natural than to suppose that the fibres for the first digit or thumb should succeed those of the index finger or second digit, and occupy what remains of the ulna on the outer side of the fibres to the index? This coronoid head of the flexor longus pollicis does lie to the outer side of indical part of the flexor profundus digitorum, and practically in the same transverse plane, and it is usually present. That

head, which sometimes comes from the inner side of the coronoid process, is a different structure altogether, and it may be, as Macalister puts it, "the remains of the obsolete superficial flexor of the pollex." If this be the case, one can understand why this occasional head arises superficially to the flexor profundus digitorum from the inner side of the coronoid process, and crosses the fibres of the indical part obliquely from within outwards, to join the main mass of the flexor longus pollicis.

If this superficial occasional head be not the remains of an obsolete superficial flexor of the pollex, but, as the text-books say, is *the* coronoid head of the flexor longus pollicis, which, as all admit, is only the specialised dismembered outer part of the flexor profundus digitorum, a muscle which at its origin around the coronoid process is of pretty uniform thickness, and whose individual parts lie side by side on the bone, succeeding one another from inner side to outer, just as the digits do, then it seems to me unintelligible why the flexor longus pollicis, the outer part of the flexor profundus digitorum, should have its coronoid head so displaced from what one would naturally call its proper position, the outer side of the indical part of the flexor profundus digitorum, as to arise superficially to the latter muscle, and have to cross it from within outwards to join the main mass of the muscle.

Long before entertaining any ideas concerning the nature of the oblique radio-ulnar ligament, my attention had been drawn to the coronoid head or heads of the flexor longus pollicis, and having, as a result, made some 400 dissections of the muscle, I feel bound to regard the normal origin of the coronoid head as from the outer side of the coronoid process of the ulna immediately to the outer side of the indical part of the flexor profundus digitorum, and practically in the same plane as that part, and to regard any other mode of origin or any other head as abnormal, or perhaps as belonging to that obsolete superficial flexor of the pollex which ought to be connected in some way with the flexor sublimis digitorum, or arise near and in series with it. And this is borne out by the fact that this so-called slip of the flexor longus pollicis does arise either just below the coronoid head of the flexor sublimis digitorum from the inner side of the coronoid process near its apex, or from the

deep aspect of that muscle itself at a variable point. Relegating this so-called head of the flexor longus pollicis to its morphological position, viz., to the flexor sublimis digitorum, and turning to what I venture to call the normal head, and keeping in mind not only its correspondence in attachments, relations, and course with the oblique radio-ulnar ligament, but the fact that this head may entirely take the place of the ligament, I think I am justified in suggesting that the oblique radio-ulnar ligament is a degenerated, dismembered, specialised part of the normal coronoid head of the flexor longus pollicis muscle which has arisen as a result of pronation and supination of the hand.

Lastly, I ought to state that this ligament is regarded by Professor Macalister as a specialised part of the sheath of the supinator brevis muscle.

AN UNUSUALLY LARGE TERMINAL VERMIFORM APPENDIX, WITH RECURVED SMALL CONICAL CÆCUM; ACCOMPANIED BY SOME REMARKS ON THE PERITONEAL POUCHES. By EDWARD FAWCETT, M.B. Edin., *Professor of Anatomy, University College, Bristol.*

MY attention was called to these interesting conditions by the inability of the dissectors of the abdomen to find the Vermiform Appendix. Knowing that this viscus often lies behind the peritoneum and the ileum, I at once directed my attention thither, and found the appendix lying behind the inner half of the ascending colon, and parallel to its mesenteric or posterior tænia. It had no mesentery of its own, but lay under cover of the left layer of the ascending mesocolon, being bound by it to the ascending colon. Its lower end seemed to be funnel-shaped, but on closer examination I felt bound to call that part the cæcum, because it was marked off from the appendix or rest of the tube by a slight constriction.

The appendix, three-quarters of an inch in width to near its upper extremity, reached the whole length of the ascending colon, terminating in a point at the junction of the lower margin of the hepatic flexure with the inner margin of the ascending colon. At its pointed extremity was attached a large appendix epiploica. Prolonged from the cæcum were the three longitudinal bands of muscle (tæniæ) which are so characteristic of the large intestine; and these extended a little more than half way along the appendix.

I have often seen and read of cases of terminal appendix, but have seen or read of nothing like this, accompanied as it was by a small conical cæcum, folded up behind the ascending colon in such a way as to be quite invisible from the front.

The *cæcum* was small, not much greater in calibre than the small intestine at its junction with the colon. It was about two inches in length, and, as seen in the accompanying diagram, which is considerably reduced from nature, was conical in shape,

and lay wholly behind the ascending colon, in such a manner as to be quite invisible from the front. It was marked off from the vermiform appendix by a slight constriction, as before mentioned.

I think it is agreed nowadays that the adult cæcum—that part of the dilated large intestine below the entrance of the ileum—is a lateral enlargement of one of the haustra of the

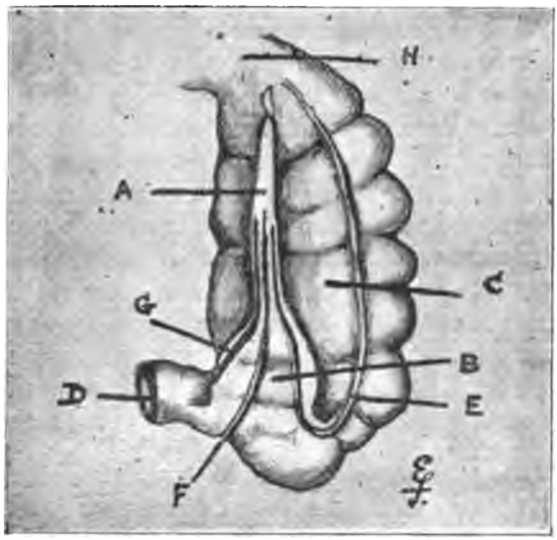


FIG. 1.—*Vermiform Appendix*, *Cæcum*, and *Ascending Colon* seen from behind:—A, vermiform appendix; B, cæcum; C, ascending colon; D, ileum; E, posterior or mesenteric tænia; F, anterior or omental tænia; G, internal or free tænia; H, hepatic flexure.

primitive cæcum, which enlargement takes place at the point where the primitive cæcum is given off from the junction of large and small intestines; that the undilated part of the primitive cæcum, becoming "small, contracted, and rudimental" (Macalister), never dilating, remains as the vermiform appendix, which, because of the lateral enlargement of the base of the primitive cæcum to form the adult and permanent cæcum, has become pushed inwards, and now appears as a small tapering tube attached to the inner side of the permanent cæcum. In this case it would appear that the enlargement has been uniform; hence its conical appearance and the apical position of

the vermiform appendix; and I suppose that, at sometime during the descent of the ascending colon, the vermiform appendix having been caught up by the peritoneum, has been fixed by it in such a way as to cause the cæcum to be folded behind the ascending colon.

Peritoneal Pouches. — There were no peritoneal pouches in this region, but there was a large duodeno-jejunal pouch present, long enough to admit the whole of the index finger, and this—though not relevant quite to the subject in hand—leads me to say that it is my experience almost invariably to find that presence or absence of the cæcal or ileo-cæcal pouches is accompanied by absence or presence of the duodeno-jejunal pouch. Why this should be I have not the least conception, but it has struck me as a remarkable coincidence. In the last 200 subjects I have had under observation, I have always, on opening the abdomen, looked at once for cæcal pouches, and am now able to predict with certainty the presence or absence of the duodeno-jejunal pouch, and to form some opinion as to its probable size.

As I have already said, I am quite unable to account for these correlations—for such they seem to be—and shall be glad to have light on the matter, and to know if they have been observed by others.

Errata to Prof. Fawcett's paper on the Structure of the Inferior Maxilla, p. 358.

Figs. 3, 4, 5, 6, 7, 8, ought to be 2, 3, 4, 5, 6, 7.
Fig. 8 is omitted.
In Reference Table, read sections 1–4 are anterior to mental foramen.
Section 5 is through mental canal.
Sections 6–13 are posterior to mental foramen, &c.

ON THE FORM OF THE SPLEEN AND THE KIDNEYS.

By D. J. CUNNINGHAM, M.D., D.C.L., F.R.S., *Professor of Anatomy, University of Dublin.* (PLATE VIII.)

TWO methods have been adopted by anatomists with the view of obtaining an accurate knowledge of the true form of the solid viscera of the abdomen. By the first of these, the organs are hardened *in situ* by an injection of from 5 to 10 litres of a ½ p.c. or a 1 p.c. solution of chromic acid under a given pressure. This is the method which was employed by Professor His[1] in the preparation of his now celebrated models, the production of which has in many respects revolutionised our ideas upon the topographical anatomy of the abdomen.

By the second method, the organs are built up by a process of reconstruction. A suitable subject having been selected, it is in the first instance frozen. The trunk is then divided by means of a saw, in the sagittal direction, into eight slabs of nearly equal thickness by seven sections. The slabs thus obtained are hardened, care being taken to ensure a uniform shrinkage of the different viscera. When the necessary consistence is attained, the different pieces of a given organ are removed from each slab in turn, cast in plaster of Paris, and then modelled in soft wood. When the various parts are completed they are fitted together, and the organ is thus reconstructed. It is obvious that this method is calculated to give very accurate results, although it is also evident that a source of error is apt to creep in through the loss of substance produced by the various saw-cuts. The amount of this loss, however, can be estimated, and, in the wooden models, added to both surfaces of the different pieces of a given organ. One marked advantage which the reconstruction method possesses consists in the fact that by the lines of union of the separate pieces we obtain very accurate information regarding the topography of an organ so recon-

[1] Wilhelm His, "Über Präparate zum Situs Viscerum mit besonderen Bemerkungen über die Form und Lage der Leber, des Pancreas, der Nieren und Nebennieren sowie der weiblichen Beckenorgane," *Arch. f. Anat. und Entwick.*, 1873, p. 53.

structed, seeing that the sections are made along certain well-established planes.

Of course, the great disadvantage of the reconstruction method is the immense amount of labour which it involves. For my own part, I may say that it would have been impossible for me to have undertaken it had it not been for the assistance which I have obtained from my working assistant, Mr John Stirling, who is a trained and exceptionally skilful wood-carver. In conjunction with him, I have reconstructed the liver of an adult male, and the liver, stomach, kidneys, and spleen of a female child. This work was completed about two years ago, and the originals were placed in the hands of Messrs Casciani & Co. in order that he might supply duplicates to those anatomists

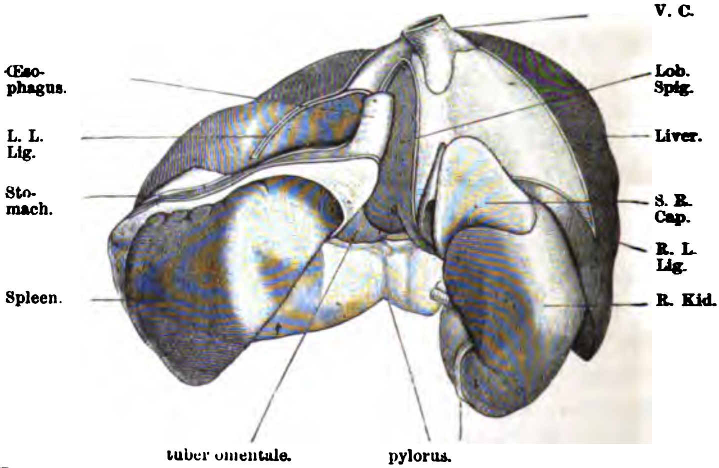


FIG. 1.—Model, produced by the reconstruction method, of the liver, right kidney, stomach, and spleen of a child.

who might desire to have them. The form, however, which was obtained for the kidneys, and more especially for the spleen, differed so markedly from that exhibited by the models of these organs produced by Professor His, that I was unwilling to publish my results until I was assured that I was not dealing with individual peculiarities.

During the last few months I have had an opportunity of checking my results by the injection method. In all, I have hardened three adult subjects, viz., two well-formed females and one male. In the first two of these I employed Müller's fluid, followed by graduated spirit injections. In the case of one of

the subjects (A) the injections were repeated almost daily for a period of two weeks, whilst in the other (B) the hardening process was continued for fully six weeks. The third subject, at the suggestion of my Assistant, Dr A. F. Dixon, I injected with a saturated solution of chloride of zinc, followed by spirit; but although this method in his hands has afforded excellent results in the case of the advanced fœtus, it was found unsuitable for the larger organs of the adult.

The viscera which I have obtained from these specially prepared subjects have satisfied me that our present description of the pancreas, spleen, and kidneys requires some modification, and that the models which had been obtained by the reconstruction method exhibit what may be considered to be the natural form of the organs.

On the present occasion I do not intend referring to the pancreas, except incidentally. A few months ago Professor Symington read a paper before the Anatomical Section of the Royal Academy of Medicine in Ireland upon the form of this organ.[1] The remarks which he then made I can corroborate in nearly every particular. Professor Birmingham has also given some attention to this matter, and I understand that it is his intention to publish shortly some additional observations on the pancreas. His results, so far as I know them from conversation with him, also agree with what I have noted in the course of my investigation.

The two livers which I have reconstructed show many interesting points, from the fact that they present two extremes in the changes of form to which this organ is subject from the modelling effect of surrounding viscera. One was obtained from an emaciated adult male, in which the hollow viscera were absolutely empty and the anterior abdominal wall greatly retracted. The organ is flattened from before backwards to such an extent that its inferior surface is almost brought to lie in the same plane as the posterior surface.

The model of the child's liver presents just the opposite condition. The colon was greatly distended, and had exercised a strong pressure in an upward direction upon the stomach and the liver. The vertical depth of the liver is thus greatly

[1] This paper has not yet been published.

reduced, and the different surfaces of the organ are all marked off from each other with the greatest precision. The slight modification of Professor His's description proposed by Professor Symington is therefore particularly applicable to this form of liver.[1]

It is to the form of the spleen and kidneys, however, that I desire specially to call attention in this communication.

Spleen.—Professor His, in the article already quoted, makes very brief reference to the spleen. He alludes to Luschka's account of the organ, and merely remarks that "the adaptation of the spleen to neighbouring viscera is known, and, by the designation of its three surfaces as superficies gastrica, superficies renalis, and superficies phrenica, sufficiently indicated." We are therefore obliged to turn to his model of the organ to obtain an idea as to the conception he has arrived at regarding its form. This model has been very generally taken as a type, and the majority of our descriptions of the spleen have been framed from it. It represents the spleen as an oval organ, narrower at

Fig. 2.—From the model of the Spleen, by Professor His. I.G, superficies gastrica; I.R, superficies renalis; I.P, area of contact with pancreas: I.C, superficies colica.

its lower than at its upper end, and with both of these extremities somewhat pointed. Its visceral aspect is divided by a salient ridge into an anterior gastric concavity, which is adapted to the fundus of the stomach, and a posterior, deeply

[1] Johnson Symington, "On certain Physiological Variations in the Shape and Position of the Liver," *Trans. Med. Chir. Soc. Edin.*, 1887.

hollowed out, narrow renal surface, which fits closely upon the convex outer margin of the kidney. The tail of the pancreas is in apposition with the lower part of the gastric concavity, but there is no impression on the spleen to mark the place of contact. When placed in position the lower end of the spleen rests upon the summit of the sigmoid flexure of the colon.

I have not met with this form of spleen in any of the subjects I have specially prepared in the prosecution of this investigation. And whilst I would be slow to insist that such a form does not exist, I have no hesitation in saying that it is not the usual nor is it the typical form of the spleen.

The spleen has the shape of an irregular tetrahedron, with its apex above and its base below. The upper extremity, which may be regarded as representing the apex, is directed inwards and upwards. It is curved to some extent forwards on itself, and not infrequently it exhibits a slight spiral twist in an outward direction. Of the four surfaces, the most extensive is the *superficies phrenica*, which is adapted to the concavity of the diaphragm, and which, as Luschka has pointed out, corresponds in position to the 9th, 10th, and 11th ribs. The remaining three surfaces are turned towards the cavity of the abdomen, and are closely applied to the neighbouring viscera. These three surfaces meet at a blunt but usually very conspicuous prominence, which may be termed the *internal basal angle*. From this, as from a centre, three ridges radiate. One salient and prominent (the margo intermedius of Luschka) ascends to the apex or upper extremity, and separates the gastric from the renal surface; a second short ridge passes backwards to the posterior basal angle, and intervenes between the renal and the basal surfaces; whilst the third ridge, less distinctly marked, proceeds forwards to the anterior basal angle, and separates the gastric and the basal surfaces from each other. The two last-mentioned ridges, together with the lower border of the organ, map out a very evident triangular area, which may be distinguished as the basal surface (superficies basalis).

The *gastric surface* (superficies gastrica) is deeply concave, and is moulded upon the fundus of the stomach. Within its area, about half an inch to the outer side of the margo intermedius, is situated the hilum of the spleen. The *renal surface*

(superficies renalis) is not concave as a rule, but flat and even. It varies considerably in extent, and is applied to the anterior surface of the upper part of the kidney, close to its outer border. The *basal surface* is smaller than the other two visceral surfaces. It looks downwards and inwards, and it has the tail of the pancreas as a constant relation. The area of contact with the pancreas is subject to considerable variation, and in many cases a marked pancreatic depression may be observed

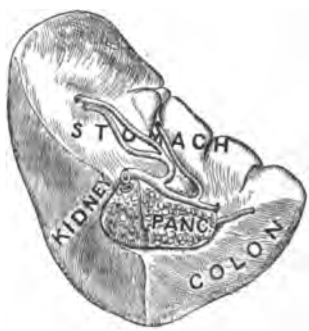


FIG. 3.—From the model of the spleen of a child, obtained by the reconstruction method. It exhibits the typical form of the spleen.

on the spleen. The pancreas stretches across the front of the left kidney, and supports the base of the spleen in a shelf-like manner. As is well known, the tail of the pancreas does not present an equal development in all subjects. In cases where it is well marked it is folded backwards upon itself as it lies in relation to the base of the spleen, and may even reach the lateral wall of the abdomen at the level of the 11th rib. The portion of the basal surface of the spleen which is not in apposition with the pancreas presents a varying relation to the colon.

The anterior border (margo crenatus of Luschka) and the posterior border (margo obtusus of Luschka) of the spleen call for no special remark, but it should be noted that the organ presents a well-marked lower border, which stretches from the posterior to the anterior basal angle, and intervenes between the basal visceral surface and the external phrenic surface.

A very characteristic feature of the typically formed spleen is the great prominence of the anterior basal angle. This con-

stitutes a striking projection, which appears to be more strongly marked in the fœtus than in the adult. Luschka calls attention to it and speaks of it, as the "spitzer Winkel" of the lower end of the spleen. It forms the most anteriorly placed part of the organ.

There is abundant evidence to show that the form of spleen which I have described is the true and natural form. It is the shape which I obtained in the model produced by reconstruction, and also in each of the subjects which were specially hardened. Dr A. F. Dixon has also observed precisely the same shape of spleen (but in a more decided form) in three advanced fœtuses (Plate VIII. fig. 1). But the morphological evidence is still more conclusive. In the Bonnet-monkey (Plate VIII. fig. 2) and the Baboon the tetrahedral form of the spleen is most marked. The same surfaces, as in the human spleen, can be detected, but these are narrower, and the organ tapers more rapidly towards the upper end. In the orang all the markings present on the human spleen can be detected, and the general outline is very much the same.[1]

In the chimpanzee the spleen is very long and narrow, and resembles in this respect the same organ in the baboon. It is, however, distinctly tetrahedral in form.

But there is another aspect of the question which is not without interest. My Assistant, Dr A. F. Dixon, in discussing the matter with me, pointed out that when an organ is packed into a more or less spherical cavity, it will occupy the smallest amount of space consistent with its bulk if it assumes the tetrahedral form. If we regard the spleen from this point of view, we must look upon the diaphragmatic surface as representing the mathematical base, and the so-called internal basal angle, where the three visceral surfaces meet, as the apex of the tetrahedron.

But it may be asked,—In the many figures of the spleen which have been published, are there none that represent the organ correctly? When we examine a number of text-books of anatomy, it is indeed as interesting as it is remarkable to note

[1] It is right to state that I have only had an opportunity of examining the spleen of one orang, and this was enlarged and in a pathological condition. Still, its general resemblance to the human spleen was most marked.

the many different and sometimes extraordinary shapes which the spleen is made to assume.[1] The only author, so far as I am aware, who gives a satisfactory figure is Luschka.[2] It is true that his description differs from mine, but then he looks at the organ from a different point of view.

It is right, also, that I should refer to a very beautiful model which I have received from my friend Dr Goubaroff, of the Anatomical Department of the University of Moscow. This represents the under surface of the diaphragm and the posterior wall of the abdomen after the removal of the stomach and intestine. It is the most exact and instructive model of the kind with which I am acquainted. In this the form of the spleen is seen to be precisely the same as that which I have obtained in my specimens; and further, the relation of the pancreas and the backward fold of its tail are exhibited with great accuracy.

KIDNEYS.—Prior to the publication of Professor His's article the majority of anatomists were content, in describing the kidney, to call attention to its general bean-shaped form, and to point out that, while both surfaces are convex, the anterior is fuller and more rounded than the posterior. Some, indeed, as for example Luschka, have asserted that surrounding organs exert little or no influence in modifying its form. Professor His, who has done so much to give us correct views regarding visceral anatomy, rightly insists that when the kidneys are hardened *in situ*, it is not difficult to prove that such a moulding influence does take place, and he specially refers to the impressions which are produced on the surfaces of these organs by the quadratus lumborum, the psoas, the stomach, the colon, and the liver. It appears to me, however, that the form of kidney which he describes is not a very usual one; and further, that the models which illustrate his description are not in every respect satisfactory.

The kidneys present many slight changes in form, according to the amount and the kind of pressure which is exerted upon

[1] Professor His has called attention to the fact that the figure of the liver given by Vesalius is in some respects more accurate than many more modern illustrations of that organ. The same might be said with still greater force with regard to the spleen.

[2] Hubert Luschka, *Die Anatomie des menschlichen Bauches*, 1863, p. 269.

them by contiguous viscera. In every case, however, and on both sides, there is on the anterior surface a point of maximum convexity,—a place where the kidney substance is raised in the form of a marked prominence or bulging, which may slowly rise from all sides to a blunt summit, as is usually the case in the left kidney, or which may extend across the anterior surface in the form of a rounded ridge, as happens more commonly in the case of the right kidney. Above and below this eminence the anterior surface falls away towards each extremity in the form of an inclined or sloping plane, of greater or less obliquity. These impressed districts indicate pressure exercised on the anterior surface of the kidney in two directions, and the intervening eminence is the result of this pressure and counter-pressure.

Upon the upper inclined plane of the anterior surface of the left kidney is placed the suprarenal capsule, the stomach, and the spleen (Plate VIII. figs. 4 and 8). These exercise a downward and a backward pressure, chiefly through changes in the condition of the stomach, although no doubt the diaphragmatic movements produce an indirect influence through both the stomach and the spleen. Upon the inferior inclined surface of the left kidney the counter-pressure is produced by the intestinal canal, which presses, as a rule, upwards and backwards.

When a number of specimens are examined, it becomes apparent that the position of the intervening eminence or anterior bulging of the left kidney is not always the same. This to some extent may be due to the slightly different position on the posterior wall of the abdomen which the organ holds in different individuals, but without doubt it is also due to the different degrees of gastric and intestinal pressure to which the organ is subjected at different times in the same individual.

On the right side the upper inclined surface is occupied by the liver, whilst in contact with the lower inclined area is the colon (Plate VIII. fig. 7). Here, also, there may be observed considerable differences in the extent of these areas, and consequently also in the position of the elevated portion of kidney surface which intervenes between them. Leaving out of sight the variations in the position of the kidney in different individuals, these alterations in the extent of the sloping surfaces

on the anterior surface of the right kidney are brought about by the changing conditions of the colon which presses on the kidney in an upward and backward direction. To this pressure the liver can only offer a more or less passive resistance, except perhaps in the case of the slight influence which it conveys in a downward direction from the diaphragm, and in a backward direction from the anterior abdominal wall.

This pressure and counter-pressure which produces so constant and so marked a conformation of the anterior surface of the two kidneys, must also exercise an important influence in maintaining the organ in its place, and securing it in that part of the abdominal cavity in which it lies.

In speaking of the areas on the anterior surface of each kidney I have used the term "inclined plane." This must not be interpreted too literally, because the districts in question are not by any means perfectly flat and even, and the term has been used merely with the view of giving forcible expression to the fact that there is a general slope from a central prominence in an upward and downward direction on this aspect of the kidney.

We shall now examine these sloping surfaces in somewhat greater detail. As already stated, the suprarenal capsule, the spleen, and the stomach are in contact with the upper inclined area on the anterior surface of the left kidney. The suprarenal capsule, as a rule, occupies a narrow district along the inner border from the level of the hilum to the summit of the organ. The spleen is in contact over an area immediately adjoining the outer convex border. The extent of this splenic field is variable —varying not only with the breadth of the renal surface on the spleen, but also with the level which is occupied by the kidney in the abdominal cavity. In some cases the surface of contact does not extend downwards lower than one-third the length of the kidney (Plate VIII. fig. 4), but in two cases I have observed it reaching down for at least two-thirds of the kidney length (Plate VIII. fig. 8). As a rule, the spleen produces a marked impression, so that when the kidney is well hardened *in situ* there is no difficulty in tracing the limits of the splenic contact on the anterior surface. As already mentioned, the models of Professor His show the spleen in contact with the kidney along

the outer margin of the latter organ. I have never seen such a relationship.

The pancreas stretches across the kidney, either immediately above or perhaps exactly over the eminence which intervenes between the two sloping surfaces on the anterior aspect of the kidney, and the area which it occupies is not unfrequently indicated by a faint impression. The suprarenal capsule, the spleen, and the pancreas cover, as a rule, the greater part of the upper inclined surface, so that only a small triangular interval is left between them, where direct contact between stomach and

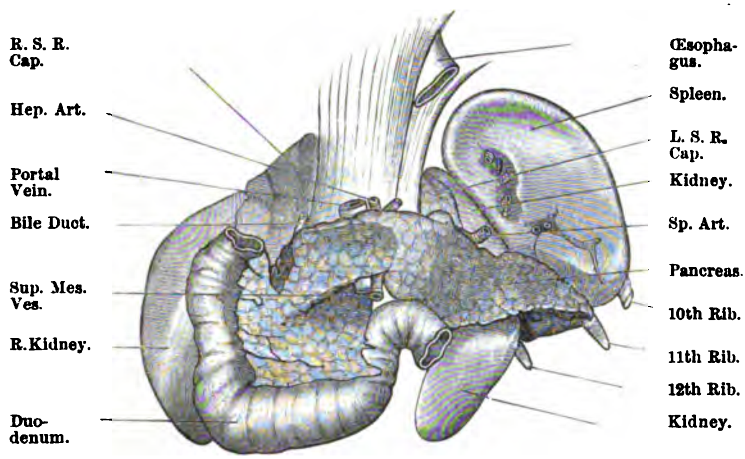


FIG. 4.—Relations of the kidneys as seen in Female Subject B.

kidney takes place. The extent of this gastric district varies greatly, but it is, as a rule, considerably smaller than is generally supposed, and I have not observed upon it that concavity referred to by Professor His. In the reconstructed left kidney of the child the stomach is crowded out altogether by a downward and backward shifting of the suprarenal capsule, and by the great extent of the splenic contact. But these conditions make no difference in so far as the pressure influence which the stomach exercises upon the upper sloping surface of the kidney is concerned, seeing that the stomach rests upon those organs which are applied to this portion of the kidney, and, as it distends, it presses through them upon the latter organ.

The inferior sloping surface on the anterior aspect of the left

kidney has a varying relation to the intestinal canal. The colon, and, as a rule, some coils of the small intestine, are in contact with it.

In the case of the right kidney the colic and hepatic impressions are usually very strongly marked, and in many cases the colic or inferior sloping surface presents a high degree of obliquity. The relation of the duodenum is a very variable one; but as I have discussed this point in a previous paper, it is not necessary to reopen the question. When the duodenum rests upon the kidney (which it almost invariably does), it gives rise to a very evident duodenal impression.

The outer convex border of kidney of both sides presents a marked thickening opposite the eminence on the anterior surface. From this it narrows in an upward and downward direction towards each extremity (Plate VIII. figs. 5 and 6). Somewhere in the neighbourhood of this marginal thickening a faint groove indicates the place where the border of the kidney is clasped by the last rib. It is interesting to note how smoothly and evenly the curved surface of the posterior aspect of the liver merges into the curvature of the outer border of the right kidney (fig. 1, p. 502). It would therefore be absolutely impossible to tell by percussion where the one organ begins and the other ends.

In discussing the characters presented by the posterior surface of the kidney, it is necessary to bear in mind that these undergo considerable modification in accordance with the different levels at which the organ is placed on the two sides and in different individuals. I have constructed the following table from the material at my disposal, with the view of forming some estimate of the extent of this variation in the topography of the kidney.

It will be noticed from the above table that the position of the kidney with reference to the vertebral column is much more constant than that which it presents to the 12th rib. Further, the position of its upper extremity would seem to be subject to much less variation than that of its lower end.

The posterior surface of the kidney exhibits two very distinct districts, viz., an internal and an external, which occupy different planes, and which meet along a vertical rounded border

Position of Kidneys with Reference to the Lumbar Vertebræ and the Last Rib.

	Right.		Left.	
	Upper End of Kidney.	Lower End of Kidney.	Upper End of Kidney.	Lower End of Kidney.
Female A.—(Hardened by repeated injections of Müller's fluid and spirit, continued for two weeks.)	Half an inch above transverse process of 1st L. V. Lower border of 12th rib extends along outer margin of kidney.	Lower border of the transverse process of the 3d L. V.	One inch above the upper border of the transverse process of the 1st L. V. Upper border of the 12th rib coincides with outer margin of kidney.	Midway beween transverse processes of the 3d and 4th Lumbar Vertebræ.
Female B.—(Hardened by daily injections of Muller's fluid and spirit, continued for a period of six weeks.)	Half an inch above upper border of transverse process of 1st L. V. Upper border of 12th rib coincides with the outer margin of the kidney.	Slightly below the lower border of the transverse process of the 3d L. V.	One inch above upper border of the transverse process of the 1st L. V. Half inch above upper border of the 12th rib.	Upper border of the transverse process of the 3d L. V.
Male.—Hardened by injections of chloride of zinc.	One inch above upper border of transverse process of the 1st L. V. Kidney lies in front of lower half of the anterior surface of the 1st rib.	Half an inch below the lower border of the transverse process of the 4th L. V.	One and a half inches above upper border of the transverse process of the 1st L. V. Kidney rises half an inch above the upper border of the 12th rib.	Lower border of the transverse process of the 4th L. V.
Model by Professor His.—**Male.**	Half an inch above the upper border of the transverse process of the 1st L. V. Lower border of 12th rib nearly coincides with the outer margin of the kidney.	Upper border of transverse process of the 4th L. V. (?)	One inch and one-eighth above the upper border of the transverse process of the 1st L. V. Upper border of 12th rib very nearly coincides with the outer border of the kidney.	Lower border of the transverse process of the 3d L. V.
Model by Professor His.—**Male.**	Two inches above the transverse process of the 1st L. V. Three-quarters of an inch above the upper border of the 12th rib.	Lower border of the transverse process of the 3d lumbar vertebra.	One inch above transverse process of the 1st L. V. Kidney rises in front of the lower half of the anterior surface of the 12th rib.	?

(Pl. VIII. figs. 3 and 9). The internal district looks almost directly inwards, and is moulded upon the psoas muscle and the crus of the diaphragm. It comprises those portions of the posterior surface which lie above and below the hilum. There is no demarcation of this district into a psoas and a diaphragmatic area. The part below the hilum and the posterior lip of the hilum, as a rule, rest upon the psoas. The internal arcuate ligament crosses the internal district immediately above the hilum, and the portion of this surface which lies above that line is in contact with the diaphragmatic crus.

The rounded ridge which separates the internal district on the posterior surface of the kidney from the external district takes a vertical direction, and corresponds in position to the outer margin of the psoas. In the upper part of the kidney, where the psoas gives place to the crus of the diaphragm, the ridge becomes rounded off, and the separation between the two districts becomes indistinct.

The external district on the posterior aspect of the kidney looks backwards, and is usually divided by an oblique furrow placed near the upper end, and which proceeds in a downward and outward direction, into a small upper area and a larger lower area.

The furrow is sometimes very strongly marked; at other times it is so shallow that it is hardly visible. It corresponds to the ligamentum arcuatum externum, and it is apt to be mistaken for a rib depression, seeing that it is not narrow, in conformity with the tendinous cord which causes it, but broad and shallow. When this part of the posterior wall of the abdomen is examined in a well-hardened subject, the rounded elevation corresponding to the external arcuate ligament is clearly visible. In the subjects which I have examined, this faint furrow or depression is much more distinctly marked on the right kidney than on the left; and this is no doubt due to the greater support which the left kidney receives from the last rib.

The portion of the external district which lies above the arcuate furrow rests on the diaphragm. This is of greater extent on the left kidney, and it is usually pressed to a greater or less degree forwards, in the manner described by Professor

His. It is very imperfectly mapped off from the upper part of the internal district which rests on the diaphragmatic crus. The intervening ridge, as we have noted, becomes rounded off at this level.

The portion of the external district on the posterior surface of the kidney, below the external arcuate ligament, is moulded upon the quadratus lumborum muscle. It comprises much the larger part of this district, and is sharply marked off from the diaphragmatic area above and the psoas area internally.

But on a successfully hardened kidney certain skeletal markings may also be detected on the posterior surface. A narrow oblique impression which corresponds with the twelfth rib can generally be detected (Pl. VIII. figs. 3 and 9). The position occupied by this differs in the two kidneys, and varies greatly in different individuals. But still further, in many cases the tips of certain of the transverse processes of the lumbar vertebræ produce corresponding dimples on the kidney immediately to the outer side of the ridge which separates the psoas imprint from the quadratus lumborum impression. In muscular and in obese subjects I question very much if any such depressions on the posterior surface of the kidney occur, but in the two female subjects which I have prepared they are well marked in each of the four kidneys. In both kidneys taken from Subject A the tips of the first, second, and third transverse processes produce the dimples; in the case of Subject B, the right kidney is marked by the tips of the first, second, and third transverse processes, whilst the left kidney is dimpled by the second and third only.

Any one who studies the changing forms of the viscera in the abdominal cavity cannot fail to observe the truth of Professor His's remarks regarding the part played by the hollow viscera in moulding the form of the solid organs. The hollow viscera are the active agents in this work, and the solid organs are as the passive clay in the hands of the modeller. Whether, under any circumstances, it is possible for a solid organ to impress a hollow viscus such as the stomach, is a question which is difficult to answer. For my own part, I am inclined to consider such a reaction impossible, or at least improbable. And this I say in direct opposition to the testimony

afforded by my reconstructed model of the stomach. In this model the wall of the stomach, where it is nipped between the liver and the spleen, shows one or two wrinkles, and the projections on the notched border of the spleen are sunk into corresponding depressions in the stomach wall. This condition I am inclined to regard as being due to *post-mortem* relaxation of the coats of the stomach. That hollow viscera exercise a moulding influence on each other no one will question. The empty bladder is frequently impressed by the intestine which lies upon it; and further, the coils of the small intestine, notwithstanding their constantly changing form, not only fit into each other with the greatest nicety, but also to some extent adjust their outlines to the opposing surfaces of the solid viscera.

EXPLANATION OF PLATE VIII.

Fig. 1.—The spleen of an advanced human fœtus, hardened *in situ* by the chloride of zinc method.

Fig. 2.—The spleen of a Bonnet-monkey.

Lettering common to Figs. 1 and 2.

S.G, Superficies gastrica.
S.R, Superficies renalis.
S.B, Superficies basalis.
A.B, Anterior basal angle.
I.B, Internal basal angle.
H, Hilum.
P, A portion of the pancreas.

Fig. 3.—Posterior surface of the left kidney of Female Subject B. Hardened *in situ* by Müller's fluid and spirit.

S.P, Impression for the psoas muscle.
S.C, Impression for the crus of the draphragm.
S.D, Surface in contact with the diaphragm immediately above the external arcuate ligament.
R.XII, Slight impression for the last rib.
$T^1T^2T^3$, Dimples corresponding to the tips of the transverse processes of the 1st, 2nd, and 3rd lumbar vertebræ.

Note the vertical ridge which separates this surface of the kidney into an internal and an external district.

Fig. 4.—Anterior surface of the left kidney of Female Subject B.

S.S, Impression for suprarenal capsule.
S.G, Area in direct contact with the stomach.
S.L, Impression for the spleen.
S.P, Impression for the pancreas.
S.I, Inferior inclined surface.

Figs. 5 and 6.—Outer convex borders of the right (fig. 6) and left (fig. 5) kidneys of Female Subject B.

Note the wedge-shaped outline of the kidneys when viewed from this aspect; also the central prominence and the two inclined surfaces on the anterior aspect of each.

R. XII, Impression for the last rib.

L.A, Groove for the ligamentum arcuatum externum on the right kidney.

Fig. 7.—Anterior surface of the right kidney of the Female Subject A, hardened *in situ* by Müller's fluid and spirit.

S.S, Impression for suprarenal capsule.

S.H, Hepatic impression.

S.C, Colic impression.

Fig. 8.—Anterior surface of left kidney of the Female Subject A. Lettering same as in figure 4.

Fig. 9.—Posterior surface of left kidney of the Female Subject B, photographed from a slightly different point of view from that adopted in the case of fig. 3. The internal and external districts are more distinctly exhibited.

Lettering the same as in fig. 3.

ARE THE EXTRINSIC MUSCLES OF THE AIR-BLADDER IN SOME SILUROIDÆ AND THE "ELASTIC SPRING" APPARATUS OF OTHERS SUBORDINATE TO THE VOLUNTARY PRODUCTION OF SOUNDS? WHAT IS, ACCORDING TO OUR PRESENT KNOWLEDGE, THE FUNCTION OF THE WEBERIAN OSSICLES? A CONTRIBUTION TO THE BIOLOGY OF FISHES.

By WILLIAM SÖRENSEN, Copenhagen.

(*Continued from page* 423.)

B. (1) *A morphological comparison between the air-bladder in the Siluroidæ and that in the other Ostariophyseæ.* (2) *Is any relation to be found between a small air-bladder in Ostariophyseæ and the habits of its possessor?* (3) *On the function of the small air-bladders found in many Siluroidæ and Cobitini* (of the family of the Cyprinoidei).

Against the theory of Weber, or rather against some of the reasons which I have advanced in support of it—especially in our times, when rudimentary organs are often, perhaps, a little too rashly supposed to be useless—might be made the following objection, which, at the first glance, seems to be a rather plausible one: In many species of the Cobitini and in many genera[1] of the Siluroidæ the air-bladder is but very small, and more or less encapsuled in bone. When these fishes are marked bottom-fishes, and such fishes having, according to my own opinion, so much occasion for sharp hearing, it is rather strange that their air-bladder is so small, as this fact must be supposed to involve a diminution of the organ's function as a resonator. Before answering this question, I must discuss: the difference between the air-bladder in the Siluroidæ and those of the rest of the Ostariophyseæ, and then elucidate the question whether Professors Bridge and Haddon are justified in supposing (*Ib*, pp. 305–308) that rudimentary air-bladders in the Siluroidæ may be

[1] The "Siluroidæ abnormales," Bridge and Haddon.

explained by "a purely ground habit of life" or "partially amphibious and gravelling habits."

1. *A morphological comparison between the air-bladder in the Siluroidæ and that in the other Ostariophyseæ.* Dr. Sagemehl (IV, pp. 11–12) says that in most of the Cyprinoidei and in all as yet examined Characini the air-bladder consists of two divisions united by a narrow duct, and that similar structures exist in the Gymnotini, only that both divisions do not directly communicate but are united by means of long narrow canals with the common pneumatic duct; while it is a rare case to find a bipartite air-bladder within the family of the Siluroids.

Professors Bridge and Haddon (I*a*, 1, p. 313):—

"*Very rarely* does it [the air-bladder of the *Siluroidæ*] exhibit the bipartite division into an anterior and a posterior sac, so characteristic of other families of Ostariophyseæ."

And (I*b*, p. 226):—

". . . it *never* exhibits that bipartite division into *simple* anterior and posterior sacs which is so characteristic of all other families of Ostariophyseæ."

At any rate the air-bladders in certain Siluroidæ can be *described* as bipartite, *f.i.* those of *Pangasius djambal* (I*b*, fig. 93, Tb. 19), *Doras Heckelii* (*Kner, Sitzungsber. d. k. Akad. d. Wiss. Wien*, vol. XI., 1853, fig. 7, nec 8), *D. dorsalis* (*ibid.*, fig. 9), where the anterior portion is great, and the posterior one small; *Platystoma Vaillantii* (*Kner, ibid.*, vol. XXVI., 1857, pp. 397–398, Tab. IV. fig. 10), where the portions are nearly of equal size; and of *Malapterurus electricus* (this memoir, in the January number of this *Journal*, fig. 8, p. 210, where the anterior portion is rather small, the posterior one great); nay in *Arius* ("Bagrus") *emphysetus* it is even by means of two constrictions divided in three portions ("hinter einander liegend . . ." according to Joh. Müller, VIII*c*, p. 157). On the air-bladder in *Piratinga* ("Pimelodus") *filamentosa*, the same author (*ibid.*, p. 140, Tb. III. fig. 7) says:—

"Dieser Fisch . . . hat zwei hinter einander liegende, ganz getrennte platte Schwimmblasen, beide durch und durch zellig, aus der vorderen geht der Luftgang, die hintere enthält nichts von einer gemeinsamen

mittlere Höhle. Das ganze Innere besteht aus kleinen lufthaltigen Zellen."

Though I never saw this species, I dare, however, say that this description is not good because Joh. Müller did not understand the morphology of the air-bladder in the Siluroidæ: his remark that the posterior "air-bladder" does not contain a central cavity is open to no doubt; but the posterior part of the air-bladder in the Siluroidæ (with well-developed air-bladder) is always devoid of a central cavity, divided as the posterior part is by a longitudinal septum; a future inquiry into the species in question will show that the pneumatic duct opens into an anterior cavity; that the two "air-bladders" are "completely separated," is quite incredible to me: probably the relations are similar to those of *Platystoma Vaillantii*, where the two portions are united by means of two canals, which are said to be widely separated from each other. Though the statement of Professors Bridge and Haddon, quoted above, that the air-bladder in the Siluroidæ never exhibits a division into *simple* anterior and posterior sacs is quite correct, they too have failed to understand the morphology of the air-bladder in this family, which deficiency has been a concurrent cause of a grave error, which they have committed in the physiological part of their work.

Morphologically speaking, the air-bladder in the Siluroidæ is never bipartite in the same manner as in the other families of the Ostariophyseæ. *For the posterior sac of the other Ostariophyseæ never exists in the Siluroidæ.*

In the Gymnotini[1] in *Pygocentrus piraya*, Cuv., and *Myletes bidens*, Cuv. et Val., among the Characini ("Lydorganer hos Fiske," pp. 94 and 96); and in *Nemachilus Strauchii*, Kessl. (my second paper, III., p. 121), among the Cyprinoidei, I have found that the pneumatic duct opens into the duct uniting the anterior and posterior sac. In Pygocentrus and Myletes the uniting duct is quite short, but in the rest of the genera mentioned here it is (relatively) long; and in *Carapus fasciatus* the duct leading to the posterior sac is much wider than the duct leading to the

[1] Viz., *Sternopygus carapo*, L., and *Carapus fasciatus*, Pall. According to Reinhardt (*loc. cit.*), also in *Sternopygus Marcgravii*, Rhdt., *St. microstomus*, Rhdt., *Sternarchus Brasiliensis*, Rhdt. The same must be supposed to be the case in *Sternopygus æquilabiatus*, *St. macrourus*, Bl., and *Gymnotus electricus*, L. (See Reinhardt, *l.c.*)

anterior one. In the Gymnotini[1] and Nemachilus it is *evident* that the posterior sac is an extension or continuation of the pneumatic duct. In Pygocentrus and Myletes the same must be the case. In the other genera, known to me, of the Cyprinoidei and Characini, the posterior sac is an immediate continuation of the pneumatic duct, while the anterior sac is a diverticulum of the posterior one. *In all three families therefore the posterior sac must be considered as the real (or main) air-bladder, while the anterior sac is a diverticulum of the air-bladder or of the pneumatic duct.* In reality the conditions are quite homologous with those in Polypterus[2], with the sole difference, that the diverticulum of the air-bladder (or of the pneumatic duct) in the Cyprinoidei, the Gymnotini, and the Characini extends in front, so that the air-bladder, considered as a whole, is symmetrical, while in *Polypterus* the diverticulum of the air-bladder, on the contrary extends behind, along the left lateral wall of the air-bladder, and accordingly this organ considered as a whole in this fish, is quite asymmetrical.[3] In many species among the Cobitini the posterior sac is reduced, nay even to nothing. And in the Siluroidæ it never exists. *For even if the air-bladder be divided into compartments, the pneumatic duct always opens into the foremost one,* immediately in front of the longitudinal septum, not only in the genera I myself have examined, but also in all the forms, of which I have been able to find any indications in this respect in literature.[4] And that the place of opening of the pneumatic duct is the main point I need hardly to prove. Hence, the anterior chamber in the anatomical descriptions (the anterior "compartment," Br. and Hadd.) of the air-bladder in the Siluroidæ, which chamber reaches to the beginning of the longitudinal septum, is the only existing part of tbe bipartite air-bladder of the other

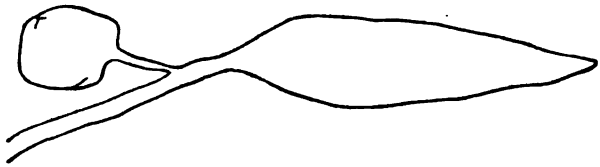
[1] I refer to my figure of the air-bladder in *Sternopygus carapo* (III., Tb. I. fig. 9).

[2] I refer to my description of this organ (IIb, p. 204). The air-bladder in Polypterus is commonly described as being simply bipartite (*i.e.*, being in the same relation to the pneumatic duct as the lungs of man to the trachea).

[3] These views I have already shown before (III., pp. 91–92).

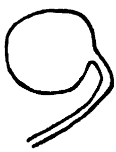
[4] Professors Bridge and Haddon, who have examined a very great number of Siluroidæ, quite agree with me on this point, saying (Ia, 1, p. 320):—"In all the normal Siluroids, without an exception, a ductus pneumaticus is present, and opens into the anterior chamber in the median line of its ventral wall, and immediately in front of the ventral margin of the primary transverse septum."

FIG. 10. *Diagrammatic Views of the Air-bladders of the Ostariophyseæ, illustrating the morphology of this organ.*



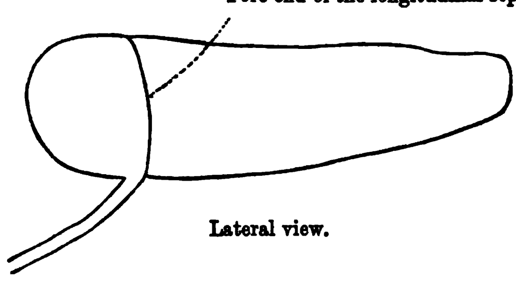
Carapus (a genus of the Gymnotini). Lateral view.

Cyprinoidei and Characini (in general). Lateral view.

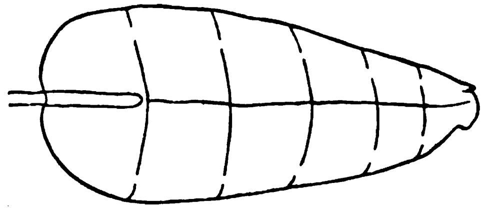


Misgurnus fossilis and Siluroids with small air-bladder (Sil. "abnormales," Br. and Hadd.). Lateral view. (The pneumatic duct is often a solid string,—nay, is sometimes not to be found.)

Fore-end of the longitudinal septum.



Lateral view.



Ventral view.

Siluroids with well-developed air-bladder (Sil. "normales," Br. and Hadd.).

Ostariophyseæ, while the posterior chambers are only backward turned diverticula of the air-bladder, which is homologous only with the anterior sac of the other Ostariophyseæ. *And it is the Cobitini which* (in this relation) *connect the Siluroidæ with the other Ostariophyseæ.*

There still remains a difference not to be unobserved between the air-bladder of the Siluroidæ and the remaining Ostariophyseæ. In the Cyprinoidei, the Characini, and the Gymnotini, the inner membrane is extraordinarily thick, and in the posterior sac it is so strongly united with the outer membrane that they cannot be separated, whereas the membranes of the anterior sac are free of each other. In the Siluroidæ the inner membrane is very thin and pellucid. In the Characini, and especially in the Cyprinoidei, the inner membrane of the anterior sac is very elastic, but in the posterior sac it is only little elastic. In *Prochilodus lineatus* (II*b*, p. 99) and *Cyprinus carpio* I have observed, that the two membranes of the anterior sac on the side which they turn towards each other, are invested with very thin serous membranes with a single pavement epithelium. Professor Charbonnel-Salle, who has not known my paper until this year, and who cannot therefore possibly have been influenced by it, has made the same observation in *Cyprinus carpio* and *Tinca vulgaris* (*Ann. d. sci. nat.*, 7 Sér., vol. II., Paris, 1887, p. 326). In the Siluroidæ I have not been able to see a similar pavement.

2. *Is any relation to be found between a small air-bladder in Ostariophyseæ and the habits of its possessor?* It is well known that the air-bladder is a very capricious organ: within the same genus, one out of two allied species may be found in possession of a well-developed air-bladder, whereas the other is totally destitute of this organ, even if the species are so very intimately allied that it is difficult to distinguish one from the other. Delaroche (XIV.) said, 85 years ago, that this organ is either well developed or totally wanting. As far as I know—and in the course of more than ten years I have studied a great deal of the literature that deals with this organ—this must still be regarded as a general rule, with one exception, however: the Ostariophyseæ. Nearly fifty years ago Joh. Müller, it is true, said in one of his most celebrated works (VIII*c*) that the air-

bladder is wanting in some genera of the Siluroidæ; by the investigations of different authors this has proved not to be the case, but the erroneous statement of Joh. Müller arose from the circumstance that in those genera (as well as in many others) this organ is very small and even encapsuled by bone.[1] Among the Cyprinoidei the genus Homaloptera was said to be destitute of the air-bladder; Sagemehl, however, has discovered it to exist (IV, p. 9, the 2nd footnote). *As to the Ostariophyseæ it must therefore be stated that, in contrast to other Fishes, the organ always exists, but is either well developed or very small.*

The excellent anatomical investigations of Professors Bridge and Haddon have proved this to be the case in a great number of the Siluroidæ. Thus they are fully justified in pointing out (I*b*, p. 306) that—

> "Two species of Cryptopterus (*C. micropus* and *C. hexapterus*) have rudimentary air-bladders, while all the remaining species of the genus that came under our notice had those organs unusually well developed."

And that—

> "In two species of this genus [Pimelodus] (*P. pulcher* and *P. sapo*) the air-bladder itself is not only rudimentary but lacks even a trace of the compressor and tensor tripodis muscles which are so characteristic of the normal *Pimelodinæ*."

There is a capriciousness then in the appearance of this organ, analogous to some degree with what is known in other fishes. And as another instance may be mentioned, what the same authors have discovered, viz. that *Pangasius micronema* is destitute of an "elastic spring" apparatus, while it exists in the four species of that genus which they have examined. This fact

[1] This always seems to be the case in the Loricariini. I may perhaps be allowed to call attention to the fact that a comparative study of the osteology of the skull in this group will be interesting in different respects. I should like to point out, for instance, that the "suprascapula" is a fusion of the following bones: suprascapula, scapula, and os occipitale externum (but not of an ossification of the pleura too). How interesting but at the same time how difficult this study will be, will appear from the fact that the late Professor H. Weyenbergh ("*Hypostomus plecostomus*, Val., Mémoire anatomique pour servir à l'histoire naturelle des Loricaires." Cordoba, 1876) has considered the first 4 (? 5) fused vertebræ (the "processus transversus" of which encloses the air-bladder) as "l'os occipitale basilare." These facts I have already shown before (II*b*, pp. 46 and 180).

bears out that, most probably, the air-bladder does not serve to produce sounds in *Pimelodus pulcher* and *P. sapo*, and that it is at least very doubtful whether it does so in *Pangasius micronema*, while it fulfils this function in the other species examined of these two genera. And in the Cyprinoidei the same is the case, viz. in the *Cobitini*: the air-bladder is either well developed and its anterior small sac encapsuled, or—what is most frequently the case—the anterior sac is encapsuled[1] and the posterior rudimentary. If you peruse the paper of Dr. Herzenstein[2] on the species of the genus Nemachilus of Central Asia, you will find that out of the 17 species treated the author says with regard to the 8:—"Die Schwimmblase besitzt einen frei in die Bauchhöhle hineinragenden Abschnitt." As to *Nemachilus Strauchii*, this "Abschnitt" is not stated to be particularly large. But, thanks to the kindness of the late Dr. Herzenstein, I have examined this species, whose air-bladder is by no means rudimentary: in a specimen of a total length (*i.e.* to the base of the caudal fin) of 9·2 ctm. the bony capsule which encloses the anterior sac of the air-bladder measures 4·75 mm. of length and 11 mm. of width; the "connecting ducts" put together 9·5 mm. of length; the posterior sac of the air-bladder 14 mm. with the largest width of 6 mm.[3] (The pneumatic duct was open.)

Professors Bridge and Haddon express the opinion that the "Siluridæ abnormales" have a rudimentary air-bladder on account of their "purely ground habit of life," or on account of their partially amphibious and grovelling habits (*Ib*, pp.

1 Of the manner in which this encapsulation takes place in the Cobitini, I have given a rather detailed account in my second paper (III, pp. 116–123; abstract in the French *Résumé*, p. 140). I here take the liberty to say that the principal part by far of the roof of the bony capsule consists in the very large transverse processes of the (true) 4th vertebra, while only a small part of the outer membrane of the wall of the air-bladder is ossified and fused with the said processes and the centrum of the vertebra, or with the processes alone. The lower "vessicular formed" part of the bony capsule is only formed by the pleura, and even most probably by its parietal lamina alone. (Cfr. Bridge and Haddon, *Ib*, p. 318.)

2 *Wissenschaftliche Resultate der von N. M. Przewalski nach Centralasien unternommenen Reisen. Zoologie.* Bd. III. Abth. II. Fasc. I. St Petersburg, 1888, folio. Dr. Herzenstein here gives to the genus Nemachilus the same extent as Day.

3 In a *Cyprinus carpio* with a total length (*i.e.* to the base of the caudal fin) of 14 inches the anterior sac of the air-bladder measured 2½ inches, the posterior 2¾ inches of length. In its broadest place the air-bladder measured 1½ inch.

305–306). But the matter is not so plain as it appears to be when we read these authors. For, as I have shown above, the Siluroidæ in general are bottom-fishes. And the Doras of Rio Parana baja and Rio Paraguay are purely bottom-fishes, and *D. maculatus* must be counted among the "Siluridæ normales." And the species of the genus Clarias, though most probably as good bottom-fishes as the European Loaches, frequently mount to the surface of the water, to inhale the atmospheric air—as do even the European Loaches. This is also the case with Saccobranchus, and, according to Jobert (IX *a* and *b*), with Loricaria, Hypostomus, and Callichthys. The "normal" Doras (from the Argentine Republic) are purely ground-fishes, whereas the "abnormal" Clarias, Saccobranchus, Loricaria, Hypostomus, and Callichthys, mount and descend.

Cuvier et Valenciennes (XV., T. XV. p. 307) say, it is true, on *Callichthys asper*:—

"Lorsque ce poisson manque d'eau, Marcgrave dit qu'il rampe sur la terre pour en chercher," and (*ibid.*, p. 313) on *C. littoralis* ("subulatus") they say, that when water is scarce, it will go down into the mud, but they add: "Ce n'est pas comme le *doras, un poison voyageur.*" And (*ibid.*, p. 279) it is stated, on the authority of Humboldt, that *Doras Hancockii wanders across* the sand; and on *Doras crocodili* they say (*ibid.*, p. 287): "il [Humboldt] l'a vu s'avancer par sauts sur une plage aride *à* plus de cents pieds de distance . . . un autre individu . . . grimpa sur un monticule de sable de vingt pieds de hauteur."[1]

Now, I have not, it is true, succeeded in finding any description of the air-bladder in these two species of Doras,[2] but I may recall to the memory of the reader that all (18) species of this and the allied genera Oxydoras and Rhinodoras examined by Kner (*l.c.*) did possess a well-developed air-bladder, furnished with an elastic spring apparatus. Now, Professor Jobert tells us that when the water is getting scarce, Hypostomus sp. and several species of Callichthys cross the land in search of other waters, but he also states Doras sp. to act in the same manner. Which species of this genus he has examined the respiration of which he has been studying, he does not mention, but as in

[1] All these statements have been mentioned among others by Day (Xa. pp. 276 and 284).

[2] The air-bladder of *D. Hancockii* is said to be represented by Kner (*Sitzungsber. d. k. Akad. d. Wiss. Wien.*, T. XI., 1853); but, in a later paper, the author tells that the species was erroneously determinated.

another paper[1] he tells us that "Doras" and "Corydoras" produce sounds by means of the air-bladder, this organ must have been well developed in the species, which he has commented upon. And as we learn from Day that "compound breathers expire in a longer or shorter period if unable to reach the atmospheric air," we have in the species of Doras examined by Professor Jobert a "normal" Siluroid, which (when in water) resorts to the surface of the water with shorter or longer intervals. In all probability, this is also the case with *D. Hancockii* and *D. crocodili.*

It is quite correct that African and Asiatic species of the genius Clarias (possessing a very small air-bladder) are known to be migrating from one water to another. But from India we know of a whole series of other fishes, which must all be supposed to creep from pool to pool during the dry season. It is true that Day (X*a* and *b*) only mentions *Ophiocephalus gachua* and *Anabas scandens* as migratory, but we have just reason to believe the same habits to be followed by *all* the species of the families Labyrinthici and Ophiocephaloidei. Now, is the air-bladder wanting in these[2] fishes? Yes, in Spirobranchus (XV., T. VII., p. 394), and Betta (XVI., T. III. p. 388); *but in all*[3] *the other genera it is well developed;* in Anabas (XV., T. III. p. 338) it extends into two "horns," which reach nearly to the caudal fin; and in *Ophiocephalus marulius* and *O. gachua,* according to Taylor[4], it has a similar shape, nay, it is even furnished with a perforated transverse septum and clothed with muscles[5]; thus it is, beyond all doubt, a sound-producing organ, and most probably a very effective one too. The air-breathing[5] *Amphipnous cuchia,* however,

[1] In "Association Française," Montpellier, 1880, p. 748. Unfortunately, I only know this paper from Troschel's record in *Archiv für Naturgeschichte,* 1881, Bd. II. p. 318.

[2] I have only taken into consideration the genera enumerated in Günther's *Catalogue.*

[3] Günther's *Catalogue,* T. III. p. 373. *Cuvier et Valenciennes,* T. VII. pp. 349, 356, 364, 385, 419.

[4] I am not acquainted with Taylor, F., "On the Respiratory Organs and Air-Bladder of certain Fishes of Ganges" (*Edinburgh Journal of Science,* New Series, T. V., 1831, pp. 33–50). What I mention of the investigations of Taylor, I have taken from an account of his paper in *Isis,* 1835 (pp. 307–315).

[5] The correctness of this statement of Taylor is proved by his indication, that the nerve leading to [the muscles of] the air-bladder springs from the eighth spinal nerve; for when the air-bladder is devoid of muscles, it only receives nerves from the *N. vagus* and *N. sympathicus.*

is destitute of an air-bladder.[1] In the flying[2] fishes, which do not only leave the water, but which do even traverse pretty considerable distances in "flying," the air-bladder is well developed; in *Exocoetus volitans* (XV., T. XIX. p. 88) it is large; in *Dactylopterus volitans* it is rather small, it is true, but still it is large enough to be a powerful sound-producing organ (V*b*, pp. 47–51).

That several species among the Ostariophyseæ, known to be ground fishes, which rather regularly resort to the surface to breathe, have a small air-bladder, is certain. It might be tempting to draw the conclusion that the exiguity of the air-bladder is correlated to these two factors. *If* they were living at the bottom of *deep* waters, so that by their wanderings up to and down from the surface, they traversed a distance where there was a difference of pressure of one or more atmospheres, then a (large) air-bladder would evidently prove "harmful" to the fish, and this habit of life would at the same time explain the air-bladder's being encapsuled in bone. The statement of Day might also serve as a confirmation of the correctness of this conclusion, when he says (XVIII., p. 121): "That no true Indian wholly marine Siluroid has its air-bladder enclosed in bone." For no fish inhabiting the ocean, is known to respire atmospheric air. I am of opinion, however, that with our present knowledge of the habits of the Siluroidæ, we ought at all events to hesitate in advancing this explanation, for three reasons: firstly, it is anything but probable that all Siluroids furnished with a small air-bladder also respire atmospheric air; secondly, the said air-breathing species of Doras contradict this explanation; and thirdly, Day points out (*ibid.*) that "amongst the Siluroids of the hilly regions, those which ascend rivers having alpine sources, have the air-vessels inclosed in bone," *i.e.*, that most of those Siluriods are inhabiting rivers with shallow waters. Let us rather confess openly that we do not as yet possess sufficient

[1] The air-bladder is also wanting in Symbranchus; several species of this genus seem to respire atmospheric air: Weyenbergh, H., "Morphologische Anteekeningen over de Proest-Alen" (*Periodico Zoologico.*, T. III., Buenos Ayres, 1882, pp. 278–308).

[2] Whether *Pterois volitans*, L., is a "flying" fish, I do not know; but if the description of Delaroche (XIV., pp. 282–283) is correct, then the air-bladder of this fish is most probably a sound-producing organ.

knowledge of the habits of life of the Siluroids furnished with a small air-bladder, so as to be enabled to point out the correlation between their habits and the exiguity of their air-bladder.

Finally I must point out that it is open to doubt perhaps, whether we are entitled to call the air-bladder in the "Siluridæ abnormales" a rudimentary organ. In *Plecostomus Villarsi*, Ltk., it is smaller than in any of the other fishes I know—and in none of the forms described by Professors Bridge and Haddon it appears to be smaller—in this species (III., pp. 125–130) it consists in two lateral completely separated parts. In a specimen which, in its broadest[1] place, between the base of the pectoral fins, was 5 ctm., each half of the air-bladder measured 7·25 mm. in length (taken across the fish) and 2·5 mm. in the broadest place.

3. *On the Function of the small Air-Bladders, found in many Siluroidæ and Cobitini* (of the family of the Cyprinoidei).—On account of the slight size of the organ we cannot possibly suppose it to be in the "Siluridæ abnormales," performing the function which is otherwise most important: to adapt the specific gravity of the body to that level of water, in which the animal has stayed for some time (Moreau). And in the forms which I have examined, Clarias, Plecostomus (and Misgurnus), it is quite impossible for me[2] to suppose the air-bladder to be a sound-producing organ. Now as the two functions which belong or which might at any rate belong to the air-bladder in the Ostariophyseæ, cannot here be assigned to it, I wonder if the reason of the organ keeping its ground so obstinately—in contrast to that which is the case in other fishes—if the reason of this fact might not precisely be that the organ is still of acoustic importance, that it acts as a resonator.

Now, let us closely observe the structure of the air-bladder and its surroundings in this case. When for this purpose I have chosen the animals whose organs in question are represented by the affixed figures, it is because these are structures which I know.

[1] In the place where the air-bladder was placed, the breadth of the body was 2·4 ctm.

[2] As I do not mean the tones of the air-bladder in any fish to be "muscular tones," intensified by the air-bladder.

Now, to begin with Misgurnus, we here have the air-bladder enclosed in a bone capsule, which is on either side provided with a large aperture covered with the fascia superficialis of the upper lateral muscles, which is in its turn covered with the tightly-fitting skin. Opposite to this aperture the upper lateral muscles are interrupted, being attached to the fore- and back-

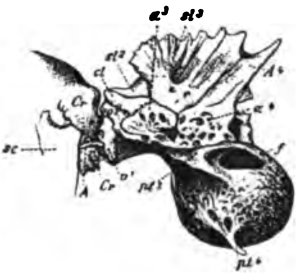


FIG. 11.

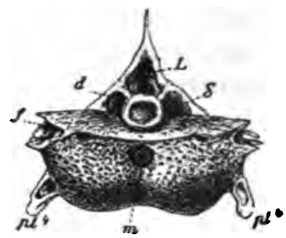


FIG. 12.

FIG. 11. *Misgurnus fossilis*, L., the hinder end of the skull, the 4 foremost vertebræ and the bone capsule of the air-bladder, seen from the left. Magnified three times.

FIG. 12. *Misgurnus fossilis*, L. The bone-capsule of the air-bladder and the (true) fourth vertebra seen from behind. Magnified three times.

Cr, the skull; *sc*, the "scapula"; A, the ligament between the centrum of the first vertebra and the scapula; *cl*, the claustrum; sl^2, sl^3, the ossa commissuralia vertebrarum secundæ et tertiæ; *f*, the lateral opening in the bony capsule of the air-bladder covered by the skin which has here been removed, corresponding with what Bridge and Haddon call the "cutaneous area"; *m*, the hindmost aperture in the bony capsule through which the air-bladder *may* project a little; *L*, ligamentum longitudinale superius; *d*, the channel (to the left) enclosing the aortæ; δ, the channel (to the right) enclosing the vena renalis; pt^2, the process of the second vertebra; pt^4, the apex of the transverse process of the (true) fourth vertebra; v^1, v^2, a^3, a^4, an aponeurosis ("saccus paravertebralis") ossified, whose single parts are fused respectively with the centrum of the first vertebra, the transverse process of the second vertebra, the neural arch of the third vertebra, the neural arch of the fourth vertebra, and the transverse process of the fourth vertebra.

side of the roof of the capsule. The large aperture then is only closed by a thin and tight membrane. In order fully to understand the figure of Clarias, the reader must fancy the very narrow slits between *p*, pt^2 and pt^3 filled out with strong aponeurotic membrane, extending distally to the skin, which here immediately touches the distal end of the air-bladder.

For this organ is placed in the space encompassed by the above mentioned parts.

I now take the liberty to ask *whether the construction of these organs does not bear a striking resemblance to the resonator which Colladon constructed* in order to hear the tones of the bell through water in his well-known experiments at the Lake of Geneva. In both cases we have a capsule with comparatively firm walls, which, on the side turned towards the sound, consists in a thin membrane. Would it be possible to imagine an apparatus constructed of animal tissues on the model of

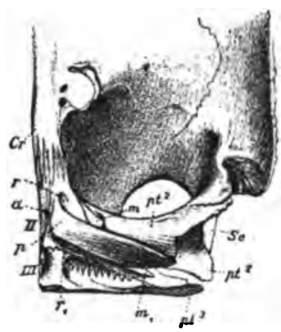


FIG. 13.

FIG. 13. *Clarias macracanthus*, Gthr. The left half of the hindmost part of the skull and the first five vertebræ, seen from below. Magnified ca. $\frac{4}{3}$. *Cr*, the skull. II, III, the centra of the apparently second (the true 2d, 3rd, 4th) and third (the true 5th) vertebræ. *Sc.*, the "suprascapula"; *m*, the anterior process of the malleus (tripus, Br. & Hadd ; *m*, the hindmost and outmost angle of the same bone; *pt*², *pt*³, the transverse processes of the apparent second and third (true 4th and 5th) vertebræ. *p*, ossification of the pleura, covering the air-bladder from below; *r*,–*r*, the channel for the left renal vein.

Colladon's resonator, more perfect than this one? I, at all events, cannot. Let me add that, supposing the capsuling to be as described, it would be, for acoustic purposes, of little moment, if the air-bladder itself were much smaller still, nay, if it formed only a compressed little thing at the bottom of the capsule, so that the vibrations into which it would be thrown, might be transmitted to the Weberian ossicles. It is quite a different thing, that this is impossible in the body of an animal, as the interstices between the tissues are never filled with air. In Plecostomus and several other genera of the "Siluridæ

abnormales" the two lateral parts of the air-bladder are completely separated, so that the saccus endolymphaticus may be influenced from the two sides separately.

Are these features peculiar to Misgurnus and Clarias? Within the family of the Cyprinoidei they are of constant, or at least general, occurrence in the Cobitini—within the Siluroidæ the same is the case in the genus Hypophthalmus[1] and the tribe Hypostomatini (or Loricariini) and this is the reason why the air-bladder was said for some time to be wanting at least in many of the genera belonging to this tribe. In this respect, I refer to the excellent memoir of Reissner on this subject.[2] The apparatus is not always equally perfect, it is true: in Plecostomus the wall which distally closes the capsule, is formed of a thinner part of the suprascapula,[3] and the interval between the bone and the distal end of the air-bladder is filled out with a tissue, rather thin though containing much fat.

Do other fishes present structures reminding us of this? Yes; within the Siluroidæ it is a thing of constant occurrence: the roof of the cavity of the air-bladder consists, to a smaller or greater extent, of bone, formed of the more or less broad transverse processes of at least the (true) fourth vertebra. And in the "Siluroidæ abnormales," in particular, it is generally the case—I refer to the work of Professors Bridge and Haddon—that the fore- and hind-edge of the roof bend downwards to enclose part of the air-bladder. And in the Siluroidæ, on the whole, it is a thing of constant occurrence that the lateral muscles of the body are interrupted for a smaller or larger space, so that part of the air-bladder is exposed to the sight if only the skin is removed. I again refer to the work of Professors Bridge and Haddon, among the figures to figg. 16, 34, 36, 51, 91, which all have reference to the "Siluridæ normales," and among which fig. 16 in particular illustrates this fact, what the authors call "lateral cutaneous areas" (*l.c. a.*

[1] Wright, R. Ramsay, "On the Skull and Auditory Organ of the Siluroid Hypophthalmus" (*Proc. a Trans. o. t. Roy. Soc. of Canada*, Vol. III., Montreal, 1886, Section IV. p. 207).

[2] Reissner, E., "Ueber die Schwimmblase und den Gehörapparat einiger Siluroiden" (*Archiv f. Anat. u. Physiol.*, Berlin, 1859, pp. 421–438).

[3] Strictly speaking, of that part of this bone, which is a dermoidal ossification.

in the figures). With regard to the air-bladder in the family of the Siluroidæ *in general* the authors say (I*b*, p. 226):—

"One of its most noteworthy features is a tendency to a lateral development, whereby the outer walls of the anterior portion become applied, through the divergence of the dorso-lateral and ventro-lateral muscles of the body wall, directly to the external skin ('lateral cutaneous areas')."

Consequently, all these features exist in those Ostariophyseæ, which live at or near the bottom in the more or less opaque fresh-water and which accordingly have small eyes and a weak sight; and the more they are distinctly bottom-fishes (the Loaches and the Siluroidæ "abnormales"), *the more fully developed are these phenomena.*

Are similar lateral cutaneous areas to be found in fishes which do not belong to the Ostariophyseæ? I am not sufficiently versed in this subject to give a full answer to this question. The number of fishes I have dissected, is not inconsiderable, it is true, but on the whole I have taken no notes on this subject. With regard to some fishes, however, I am able to state that such is the case, viz., *Diodon hystrix* (II*b*, p. 135), *Tetrodon fahaka* (II*b*, p. 139), and *Balistes vetula* (II*b*, p. 171). That these areas are here in some way connected with the transmission of the sound to the water, I do not doubt, but I dare not positively insist on it. In his above-mentioned paper (XII.) Professor Mobius shows, particularly in fig. 1, that part of the air-bladder is covered with a lateral cutaneous area, and, as I have mentioned before, he felt on the outer side of the animal a vibratory motion of this part of the skin, when the fish was drumming, and he says, in heavier types: "diese [the air-bladder] pflanzt ihn [the sound] durch die beiderseitigen beweglichen Hautplatten in das umgebende Medium fort." And I can state it with absolute certainty as to *Doras maculatus*, for (see above, p. 421), I have *felt* the mentioned part of the skin vibrating at the same time as I *heard* the sound and *saw* the air-bladder vibrating. But, if such a part of the skin is *particularly* adapted to transmit sound-vibrations from the air-bladder to the water, *it is evident that it must also be particularly adapted to transmit sound-vibrations from the water to the air-bladder.* If Professors Bridge and Haddon had known the

contents of my book "Lydorganer hos Fiske," then they would have known, to which end the "lateral cutaneous areas" are serving, which have caused them so much trouble.

The Theory of Hasse.

For half a century, Weber's theory remained undisputed; then it was found less satisfactory by Professor Hasse, who suggested,

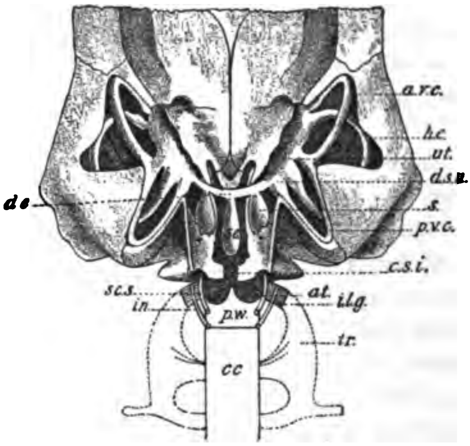


FIG. 14.—*Macrones nemurus*, Cuv. et Val. The roof of the skull having been removed; the membranous labyrinth *in situ*, so as to show the relations of the latter to the Weberian ossicles; semi-diagrammatic, × 4; *a.v.c*, anterior semicircular canal; *h.c*, horizontal semicircular canal; *p.v.c*, posterior semicircular canal; *ut*, utriculus; *s*, sacculus; *d.e*, ductus endolymphaticus[1]; *s.e*, sinus endolymphaticus[1]; *c.s.i*, cavum sinus imparis; *at*, atrial cavity; *sc.s*, spatulate process of the scaphium[2]; *in*, intercalarium[3]; *tr*, tripus[4]; *c.c*, complex centrum[5]; *pw* must be the centrum of the first vertebra. (Copied from Bridge and Haddon.)

instead of this theory, that the function of the Weberian ossicles is that of informing the animal of the greater or smaller degree of pressure, exercised by the gaseous contents of the air-bladder against the walls of this organ, according to the lower or higher level which the fish occupies in the water.

[1] = saccus end. Nussbaum. Ductus endolymphaticus + saccus endolymphaticus = sinus impar, Weber.
[2] The scaphium, Br. and H. = stapes, Web.
[3] = incus, Web. [4] = malleus, Web.
[5] Composed by the centra of the *true* 2nd, 3rd, and 4th vertebræ.

I have formerly (III, p. 70, the footnote) tried to point out briefly that, according to my opinion, this theory is not tenable; but as Professors Bridge and Haddon have adopted it—they at least have judged so themselves—I *must* enter upon a more detailed examination of the weight of those reasons on which this theory is based.

Weber (XVII., pp. 42–45) had found that the sacculi of the auditory organs in *Silurus glanis* and several Cyprinoidei were interconnected by means of a channel (*d.e*, fig. 14), prolongated behind into an unpaired, median tube or sack (*se*, fig. 14), which was separated along with the sacculi, by means of a thin bony plate, from the medulla oblongata, which was placed above. The channel, with its median tube- or sack-shaped prolongation he called the "sinus auditorius imparis," and the cavity occupied by the said sack he called "spelunca sinus imparis"; later it has been called by Hasse "cavum sinus imparis." According to Weber, the spelunca sinus imparis was completely filled out with the sinus impar; and through two small holes beneath the foramen magnum, the sinus impar communicated, in his opinion, with the "atria sinus imparis," whose outer wall was formed by (the claustrum and) the stapes.

In his memoir on the ear of fishes Professor Hasse[1], with regard to the Cyprinoidei, arrived at the result not only that the atria sinus imparis communicated with the *cavum* sinus imparis *and not with the sinus imparis itself*, but also that the intercommunicating channel, which exists between the two sacculi, *had no prolongation behind into the cavum sinus imparis, so that this space was only filled with perilymph* contained in the interspaces of an oily reticular connective tissue; in different words: the sinus endolymphaticus (Br. and Hadd., *s.e*, fig. 14) does not exist. To prove that I am not mistaken on this most important point, I will have to quote a few statements of the author (XIX., p. 472):—

"Der sinus impar ist nach meiner Auffassung *nur* eine einfache, kurze, cylindrische, dünnhäutige Verbindungsröhre zwischen den sacculi beider Seiten . . . . . *Nie habe ich den sinus impar sich in eine, in der cavitas gelegene Röhre fortsetzen sehen* . . . . ."

[1] XIX: Hasse, C., "Das Gehörorgan der Fische" (*Anatomische Studien*, Bd. I., Leipzig, 1873, pp. 417–488).

He *therefore* thought that the variations of pressure effected by the movements of the Weberian ossicles had no influence—or very little—on the endolymph of the sinus impar, as he too called the interconnecting canal between the two sacculi; but he assigned (XIX. pp. 471–472) to the ossicles the function of informing the fish of the volume of gas contained in the air-bladder ("Füllungszustand") and of the dilatation (respectively diminution) of different places of the air-bladder, as he suggested a pressure to be effected on the brain by means of the Weberian mechanism.

In a later memoir [1] Professor Hasse has exclusively dealt with the relation between the air-bladder and the ear in Cyprinoidei and Clupeoidei in view. With regard to the anatomical features he maintains the result stated in his first memoir, that the cavum sinus imparis does not contain any prolongation behind of the sinus impar, so that the sinus endolymphaticus of fig. 14 (of my memoir) is wanting. I might quote many passages in support of this, but I shall limit myself to the following (XX., p. 599):—"Die Cavitas sinus imparis enthält *nur* das ölhaltige Gewebe, welches überall in der Schädelhöhle angetroffen wird." And in this memoir (p. 583) evidently enough he states, what were his reasons for his opposition against the theory of Weber. In this second memoir, however, Professor Hasse is of opinion, that the variations of pressure will assert themselves on the spinal cord rather than on the brain; and that the variations of pressure on the spinal cord will assert themselves the more, the more quickly variations of pressure on the air-bladder follow one another, "wie solches ja. z. B. bei nahe der Oberfläche schwimmenden Fischen bei bewegtem Wasser der Fall [ist]" (XX., p. 596). He will not entirely reject the possibility of the movements of the Weberian ossicles affecting the ear, but he considers this to be of slight importance (XX., p. 585). That the author was not quite satisfied with his own theory, is evident from the following passage (XX., p. 598):—

"Ich würde mich herzlich freuen, wenn es gelänge, eine andere Theorie, als die meinige, deren schwache [physiological] Fundamente ich sicher nicht verkenne, und die ich nur *faute de mieux* aufgestellt [habe], allseitig zu begründen."

[1] XX: Hasse, C., "Beobachtungen über die Schwimmblase der Fische" (*Anatomische Studien*, Bd. I., Leipzig, 1873, pp. 583–610).

But so certain did Professor Hasse feel as to the correctness of his *anatomical* investigations, that (only as a probability, it is sure) he (p. 593) supposes the sinus impar (*i.e.*, the ductus endolymphaticus, *d.e*, fig. 14 of my memoir) to be seen neither by Weber nor by any other author previous to himself.

I have examined the auditory organs of *Cyprinus carpio.* To the best of my understanding, Weber is right, at all events as to the main question[1], viz., whether the intercommunicating duct between the sacculi of the two ears sends a median sack-shaped prolongation backwards into the cavum sinus imparis. I have seen no reticular connective tissue, not even a vestige, around the saccus endolymphaticus, or in the atria sinus imparis. If, however, you are not careful completely to remove the oily connective tissue (the arachnoideal tissue) in front of the cavum sinus imparis, or around the stapes before opening the cavum sinus imparis, or the atria sinus imparis, a few droplets of oil may easily slip in, and thus make it appear as if this kind of tissue existed inside.[2]

But I will not lay much stress on my examination on these structures, knowing as I do how much we are exposed to mistakes, when we are not familiar with the organ that is the object of our examination. It will therefore be worth while hearing the opinions of other authors since the time of Hasse.

In his extensive monograph on the ear of the Vertebrata, Retzius[3] has examined the Cyprinoid *Leuciscus idus* (p. 78). And on this subject he says :—

"Ueber der Macula ungefähr mitten am Sacculus findet man am auspräparirten, membranösen Gehörorgan ein rundes Loch, von welchem eine kurze Röhre mit mehr oder weniger fetzigen Rändern

[1] But, on the other hand, as far as I am able to see, I am of opinion, that Weber was wrong in considering the atrium sinus imparis as part of the labyrinth proper. All authors later than Hasse have arrived at the same result. When I (III., p. 70) criticised the theory of Hasse, I contented myself with mentioning this discovery of Hasse's, afterwards confirmed by other authors, though strictly speaking, it was not quite correct not to enter more fully upon the point which Hasse himself considered to be the most essential, viz., the contents of the cavum sinus imparis. But it was not for anatomical reasons that I then considered the theory of Hasse to be untenable.

[2] It is well worth noticing that Professor Hasse himself says (XX., p. 591): "Das atrium ist mitunter von einer klaren, serösen Flüssigkeit erfüllt." For this passage confirms my statement.

[3] Retzius, Gustaf, *Das Gehörorgan der Wirbelthiere*, I., Stockholm, 1881.

nach innen hin entspringt. In dieser Röhre hat *Hasse* eine Communicationsröhre erkannt, welche bei den Cyprinusarten quer durch den *sinus impar* zwischen den Sacculi der beiden Gehörorgane verläuft und dieselben also in gegenseitige, offene Verbindung setzt, ohne mit dem *Sinus impar* selbst zu communiciren. Die Präparation der sehr dünnwandigen Röhre ist in der That ziemlich schwer, indem sie leicht zerreisst. Jedoch gelang es mir, die Angabe *Hasse's* zu bestätigen; die Röhre läuft, dicht hinter der vorderen Oeffnung des Sinus impar, quer durch *diesen Raum*, verschmälert sich etwas nach dem Abgang aus den Sacculi und bildet eine offene Communication zwischen ihnen; sie erweitert sich aber gegen die Mitte des *Sinus impar und scheint hier eine sackförmige Ausbuchtung zu bilden;* mir schien diese Ausbuchtung sogar eine Strecke weit nach hinten in den *Sinus* zu reichen; *sie ist, wie die Röhre selbst, mit einschichtigem Pflattenepithel bekleidet.*"

By a cursory perusal of this passage, we may easily be impressed with a belief that Retzius confirms the correctness of the statement of Hasse. But on a closer examination, it will be seen that Professor Retzius, to whom this question was only of secondary importance, was not fully aware of the discrepancies between Weber and Hasse: therefore he always uses the expression "sinus impar" for "cavum sinus imparis"; and although it is evident that he has not paid any particular attention to this feature[1], still, that which I have taken the liberty to italicise, proves him to share, in the main, the opinion of Weber.

In the very same year, Nussbaum[2] published an investigation on the ear of Cyprinoids (principally *Cyprinus carpio* and *Carassius vulgaris*). He finds the sacculi to be connected by means of a transverse canal, which sends a large sac-forming prolongation ("saccus endolymphaticus") into the anterior part of the cavum sinus imparis in which it is *freely* placed. In accordance with Retzius, he states the saccus endolymphaticus to be invested with an interior pavement epithelium.

[1] Among the Siluroidæ, in which he has examined the ear, Professor Retzius has in Malapterurus seen only the opening of the sinus impar in the sacculus; in Silurus he has not even mentioned such an opening.

[2] Nussbaum, J., "Über das anatomische Verhältnis zwischen dem Gehörorgane und der Schwimmblase bei den Cyprinoiden" (*Zool. Anzeiger*, IV., 1881, pp. 552–556). A more detailed account he is said to have published in the journal *Kosmos*, Lemberg, 1883. But as I do not understand the Slavic languages, I have not made it a point to get hold of this journal, which our public libraries do not possess.

Three years later, the ear of the Siluroid *Amiurus catus* was examined by Professor Ramsay Wright.[1] In his part of the interesting anatomical monograph of this animal, undertaken by several Canadian naturalists, he says (p. 375):—

"In front and behind that plane they [the labyrinths] diverge from each other, but where they are nearest are connected by a short, thin-walled, transverse ductus endolymphaticus, *which sends back a pyriform thin-walled saccus endolymphaticus* (sinus impar) *into the cavum sinus imparis*, but by no means filling up the cavum."

The opinion of Professor Ramsay Wright does not accord very well with the theory of Hasse, as may be seen from the following quotations (p. 383):—

". . . . the spoon-shaped process of the stapes moves inwards, the cavity of the atrium sinus imparis is diminished, and the contained fluid urged onwards. As the result of more fluid being forced into the cavum sinus imparis, the saccus endolymphaticus which floats freely in it must be compressed, and a current of endolymph urged forwards which must impinge very directly on the macula acustica sacculi of each side. . . . . In any case, altered tension in the anterior part of the air-bladder will be brought within range of perception by the auditory nerve." P. 384:—"Whether the sac, receptaculum dorsale, acts as a reservoir for this fluid or serves to receive any excess driven out of the atria, I am unable to say, but its distension is not likely to produce any immediate effect on the spinal cord, separated as it is from it by the thick cushion of loose adipose tissue which would entirely redistribute any pressure. That the forward movement of the fluid in the cavum sinus imparis should have any direct effect on the base of the brain, as suggested *also* by Hasse, is, I conceive, improbable, owing to the thick cushion of adipose tissue[2] which separates the brain from the floor of the skull. I am inclined to believe, then, [➤→] *that it is solely through the auditory nerve, and specially through its saccular branches, that the central nervous system is informed of the movements of malleus and stapes, and consequently of the state of distension of the air-bladder* [←◄]. It is probable that the currents in the endolymph produced in this way are different in character from those brought about by *ordinary* sound waves; but, on the other hand, *the difference is not likely to be of such moment as to remove the phenomena in question entirely from the domain of sound.*" And (p. 385):—"But in Amiurus the fluid in the atria and cavum is not imbedded in the meshes of the reticular tissue, the wall of the saccus endolymphaticus is so thin that any motion in the surrounding fluid must disturb its contents, and the currents so produced must certainly affect the

[1] Wright, R. Ramsay, "On the Nervous System and Sense-Organs of Amiurus," *Proc. of the Canadian Institute*, Vol. II. Fasc. 3, Toronto, 1884, pp. 352-387.

[2] The same is the case in *Cyprinus carpio.*

neuroepithelium as much if not far more than the currents produced by *ordinary* sound waves."

Now, Professors Bridge and Haddon have not only adopted the theory of Hasse, but they even say on the subject of this theory (p. 282):—

> ". . . . . this, in our opinion, is the only conclusion that has any foundation in fact." And (p. 283):—". . . . . this theory, against which no *anatomical* objections can be urged." And (p. 284):—" *Considered solely from an anatomical standpoint*, and with the qualification which the absence of direct experimental evidence imperatively demands, it may be affirmed that *Hasse's theory is correct* . . . . ."

As they have now pointed out, and with so much emphasis, the correctness of the theory of Hasse, have their investigations on the auditory organ, then, led to the same result?

By no means. The species, the anatomy of which they describe first and most fully, *Ib*, pp. 68–100, is *Macrones nemurus.* On the auditory organ of this fish they say (p. 80):—

> "At a point where the two canals unite the ductus endolymphaticus gives off a median, pear-shaped, and extremely thin-walled sinus endolymphaticus (the 'sinus impar' of Weber), which projects backwards into, and almost fills, the cavum sinus imparis."

This species is the only one, whose ears have been represented in drawing; and the figure (Pl. XI. fig. 9), indeed, is in perfect accordance with the words here quoted. On account of the semi-diagrammatic quality of this figure, it is exceedingly clear, for which reason I have taken the liberty to copy it in fig. 14 of this memoir.

Professors Bridge and Haddon having, in accordance with all authors, at least all those whom I know of[1] who have examined the ear of the Ostariophyseæ posterior to Hasse, arrived at a result which on the main point is in direct opposition to the investigations of this author, and having thus in reality cut away the foundation of this theory, have not Professors Bridge and Haddon, at all events with regard to the results of the pressure exercised on the perilymph by the stapes, formed an idea quite different from that of Professor Ramsay Wright?

[1] With the exception, however, of Sagemehl; for, as will be shown further on, as to the Characini, we learn nothing in this respect.

They quote (*Ib*, p. 267) the statement I have above extracted from p. 383 of Ramsay Wright's paper, and that part of the passage of this author on pp. 384 and 385, which is placed between the two arrows. No doubt, in order to invalidate his arguments? Before quoting the first of his statements, they say:—

"Ramsay Wright has briefly discussed the influence exerted by the movements of the scaphia [stapedes] on the fluids of the membranous labyrinth, *and with his conclusions we entirely agree.*" And before quoting the second passage, they say:—"*Hasse's suggestion* that the propulsion of fluid into the atrial cavities and the cavum sinus imparis may, by radiation of pressure, directly stimulate either the spinal cord or the base of the brain, *has been successfully opposed by Ramsay Wright.*" Finally, before quoting the third statement (*Ib*, p. 275) they say:—"On this point we quite agree with Ramsay Wright's remarks on the Siluroid *Amiurus catus*, which are in complete agreement with our own observations on *Macrones nemurus;*" while in the quotation of his words, the word "ordinary" has slipped away from the authors, and thus, undoubtedly, Ramsay Wright's opinion (with regard to the function of the Weberian ossicles) is in accordance with their own.

With regard to the "Siluroidæ normales" the authors say (*Ib*, p. 233):—

"In all cases we found a transversely disposed ductus endolymphaticus connecting the two sacculi, and, attached to the ductus, a median pear-shaped sinus endolymphaticus projecting backwards into, and almost completely filling, the 'cavum sinus imparis.'" But on the other hand they have found (*Ib*, p. 304) "that in, at least, some *Siluridæ abnormales* the sinus endolymphaticus has completely disappeared, although the ductus endolymphaticus, the cavum sinus imparis, and the atrial cavities remain, and retain also their normal relations to one another and to the scaphia [stapedes]."

In perusing, however, with attention the anatomical descriptions of the species examined, you will find that in one species only, viz., *Glyptosternum platypogon*, the specimens were so well preserved that the authors must be certain that it was not due to the bad condition of the specimen if they did not find the sinus endolymphaticus. But this organ being extremely delicate and the cavum sinus imparis being present, I have due reason to believe that the organ must have existed nevertheless; the reader will bear in mind the negative result of the investigations of Professor Hasse. I admire, indeed, the anatomical skilfulness of the authors in discovering the organ in so many species as they have done.

Beside the above mentioned main reason for opposing against the theory of Weber, Hasse lays some stress on the circumstance that the perilymph of the cavum sinus imparis and that of the atria sinus imparis are contained within the interspaces of an oily reticular connective tissue in the species of Cyprinoids which he had examined. Professors Bridge and Haddon (*Ib*, pp. 275–276) are of opinion that the force of this objection is mitigated to some extent in the case of the Siluroidæ, as such a reticular tissue is not found in the said caves of these fishes; however, they judge this objection to be of considerable force when applied to the Cyprinoidei, nay, even to all other Ostariophyseæ. After having examined *Cyprinus carpio*, I venture decidedly to deny the existence of this tissue also in this fish. But what then is the reticular connective tissue, found by Hasse in the cavum sinus imparis? The answer to this question appears to me to be no difficult matter. In the cavum sinus imparis, Hasse has found the said tissue and not the saccus endolymphaticus, whereas those authors who have found the saccus endolymphaticus in the cavum did not find the said tissue. Hence it appears clear to me, that this "reticular connective tissue" is the very saccus endolymphaticus, in the preparation of which Professor Hasse has not succeeded, and which, therefore, has taken the appearance of being "reticular."

Hasse is of opinion that the conditions will be the more favourable to the transmission, through the Weberian ossicles, of the variations of pressure of the gaseous contents of the air-bladder, the more quickly the variations of pressure follow one another, "when, *f.i.*, the fish is swimming near the surface of troubled water." But exactly in this case, the variations of pressure of the air in the air-bladder must be *exceedingly* slight and faint, the body of the fish, like all other bodies near or in the surface of the water, must follow the up- and downgoing movements of the waves; and in accordance with this fact, Hasse is of opinion that the Weberian mechanism reacts on the slightest variations in the volume of the air-bladder. But, as Professors Bridge and Haddon adopt the theory of Hasse, they must, at all events, I suppose, be of opinion that these are the conditions most favourable to the supposed operation of the Weberian mechanism? Let us hear their own words (*Ib*, p. 264):—

"Hence, it may be concluded that relatively slight incursions or excursions of the anterior process of the tripus [malleus] will produce no effect on the scaphium [stapes], and that only movements of the tripus, of greater amplitude than those[1] now under consideration, are competent to bring about corresponding movements of the scaphium, or affect the fluids of the internal ear."

Thus we have seen, that Professors Bridge and Haddon (1) have, like their predecessors, taken away the anatomical foundation of the theory of Hasse; (2) have pointed out, in opposition to Hasse (but in accordance with Weber), that it is the ear which is affected by the activity of these ossicles; (3) have suggested that these ossicles will produce no effect whatever under the conditions which Hasse judges to be the most favourable. The reader will perceive that, consequently, it is an error, when the authors assert, repeatedly and with great emphasis, that the theory of Hasse (such as it has been propounded by this author himself) to be in perfect harmony with the facts of structure and—this must to them mean the same thing—with their own views. Our authors meaning to have adopted the theory of Hasse as well as their rejecting my "theory" concerning the function of the extrinsic muscles and the elastic spring apparatus is based on the same fact: their want of knowledge of my premises as well of those of Hasse.

I do not think it a very easy matter to enumerate *many* species among the Ostariophyseæ (even among the Siluroidæ) living at a depth of 6–10 fathoms. And these animals, among which many species live at a depth of 1–2 fathoms, nay even at less than 1 fathom, were to be so sensible to variations of the *pressure* of the superincumbent water as to have particular of this (to use Hasse's own words) so complicated apparatus between the air-bladder and the *auditory* organs, whereas fishes known, *f.i. Lota molva*, to remain now at a depth of 300 fathoms (*i.e.* exposed to a pressure of more than fifty atmospheres) and now again at a depth of a few fathoms, are not furnished with any connection between the air-bladder and brain, spinal cord or ear.

[1] Viz., slight movements. It certainly is in opposition to Weber's theory that they urge this objection. But as both Weber and Hasse are German authors, the German proverb must apply to both:—"Was dem einen recht ist, ist dem anderen billig."

What appears to me to bear out against the correctness of the theory of Hasse, is the circumstance that when the fish does not move far from that level of water, where its body, by means of the air-bladder, is brought into equipoise with the surrounding medium, this will be no drawback to the animal; but when the fish moves a rather considerable distance from that level, so that the conditions of pressure in and outside its body are continually different, then such a difference of pressure will be distinctive in any part of the animal's body, and may therefore easily be perceived. And I may be allowed to add that I have exerted my brain to find any fact in the anatomy and biology of the Ostariophyseæ, which might serve to support the theory of Hasse beyond the anatomical reason, which he himself has urged, viz. that the Weberian ossicles do not connect the *ear* with the air-bladder; but this reason may now, on the authority of later authors, who agree in the main, be considered as an error.

Justice bids me point out, that Hasse set forth his theory in the year 1873, *i.e.* before Moreau published, in 1876, his investigations on the functions of the air-bladder; for these investigations are epoch-making with regard to our knowledge as to the signification of this organ.

The Theory of Sagemehl.

When Dr. Sagemehl published his memoir on this matter, eight years had already passed since the publication of the often-mentioned investigations of Moreau. Though it is hardly possible to discuss with some success the signification of the air-bladder without a thorough knowledge of this said memoir of Moreau's, Dr. Sagemehl, however, quite[1] ignored the existence not only of these investigations but also of the whole series of more or less eminent French authors (from Biot), who in various ways, and to a greater or smaller extent, have contributed to elucidate the activity of the air-bladder. The premises from which this author has departed, are the theories of Borelli and Joh. Müller. He himself goes on theorising on

[1] When formerly (III., pp. 70–71, the footnote) I shortly criticised the theory of Sagemehl, I employed the mildest expression imaginable, that he did not appear to have fully familiarised himself with the investigations of Moreau.

the function of the air-bladder in the Ostariophyseæ particularly. Without sharing the scruples entertained by Hasse he declares the objections of this author against the theory of Weber to be of great importance. As he, however, makes the anatomical investigations of Retzius on the ear of the Cyprinoidei to be in conformity with those of Hasse, it is evident that he has not understood that which is the main point of the opposition of Hasse against the theory of Weber. He adds that his own investigations of the ear of the Characini and Gymnotini have shown the same type as has been found in the Cyprinoidei by the two previous authors. His own investigations[1] of the structure of the ear in the Characini therefore give no elucidation concerning the one point which must in this respect be regarded as the most essential one, viz. whether the saccus endolymphaticus exists or no. (As he states the existence of the cavum sinus imparis, it is near to suppose, however, that the usual contents of this cave in the Ostariophyseæ, viz. the saccus endolymphaticus, must exist too.)

To the bipartition of the air-bladder in the Cyprinoidei, Characini, and Gymnotini he attributes the meaning that the variation of volume of the gas contained in the air-bladder which will take place when the fish mounts or descends in the water, will find their expression almost exclusively in corresponding alterations in the size of the anterior sac, on account of the highly elastic nature of the walls of this division, and accordingly the Weberian mechanism will be more intensely influenced. In the Siluroidæ, where the air-bladder but very rarely presents a bipartition, the author is of opinion that the same result is attained by means of the air-bladder extending as far as to the skin.

Now the author suggests that the function engrafted on the Weberian mechanism is not to indicate to the fish which is the level of the water in which it is swimming, but to inform it of variations of pressure of the atmosphere. In other words: while Hasse considers the air-bladder with the Weberian mechanism as a manometer, Sagemehl regards it as a barometer. The author tells us that he has been carried to this result by "a

[1] Most explicitly Dr. Sagemehl describes the auditory organs in the Characini, pp. 81–85.

whole series of facts," but he fails to inform us of the nature of these facts.

Let us imagine the case supposed by the hypothesis: Let the barometer be sinking or rising even at an enormous rate, let us suppose it to sink (or rise) 10 mm. in the course of one hour —the hypothesis cannot very well ask for more. It is quite obvious that this will involve a slight dilatation (or a compression) of the air-bladder *on condition that the fish remained immovable on the same spot.* If in the course of the hour it sank (or rose) 136 mm., no influence whatever would be exercised on the volume of the air-bladder. And it is a positive fact that the European Ostariophyseæ do not hesitate to rise or descend, in the course of a few moments, much more than 150 or 200 mm. And even the smallest removal vertically from the animal's original position, would imply a disturbance of its perception *ex hypothesi* of the atmospheric pressure.

The Theory of Bridge and Haddon.

It is a matter of course that Professors Bridge and Haddon have not adopted the theory of Dr. Sagemehl; but they have been highly influenced, however, by him, especially by his sweeping assertion that the theory of Weber nowadays is generally abandoned. That the theory propounded by them—which is not identical with that of Hasse—that the function of the Weberian ossicles should be that of informing the animal, by affecting the auditory nerve and especially its *saccular* branches, of great but not of small variations in the volume of the air-bladder, that this theory is wrong, I am able to prove in two ways, both directly and indirectly.

Experiment F.—Of a lately killed *Cyprinus carpio* I laid open the Weberian ossicles in their whole length as far as the fore-edge of the os suspensorium; then I opened the abdomen, ligatured the pneumatic duct, took out the intestines with their appendages and set free the posterior sac. The air-bladder was considerably but not abnormally distended. My friend, Mr August Krogh, was kind enough to assist me in this experiment. We were now able to distend the elastic anterior sac, the only one interconnected with the Weberian ossicles, to a great extent by pressing on the posterior one. It is true that, when—in

accordance with the manner in which variations of the volume of the air-bladder must take place, when the fish is moving upwards in the water—by a gradually increasing pressure on the posterior sac, we enlarged the volume of the anterior one, we were able to ascertain a movement of the Weberian ossicles. This movement, however, we were only able to distinguish, when having fixed a needle through a thick part of the flesh of the fish, so that its end pointed to and nearly touched some part or another of the Weberian mechanism, *f.i.*, the lower edge of the incus near its distal end, we regarded, by means of a lens of high power, the spot thus accurately indicated. *The excursions of the Weberian ossicles, when by gradually increasing pressure on the posterior sac we enlarged the volume of the anterior sac, even up to double its volume, were however perceptibly slighter than those effected by a quick but slight pressure as in the Experiment D.*

The same experiment was made on another Carp; but before we set to work, I first cut the pneumatic duct and drove out part (about one-third) of the air contained in the air-bladder. Then I ligatured the pneumatic duct and we made the same experiment as on the former specimen. Now, as the air-bladder was not distended, it was much easier for us to produce variations, and even great variations of the volume of the anterior sac. We saw the very same thing as in the former specimen. At last we pressed all the air into the anterior sac, so that it was strained to a very great degree, and by means of a sharp and very pointed knife Mr Krogh cut a great transverse fissure in the wall which, on account of its great elasticity, was contracted almost instantly, while through a lens I regarded one point of the Weberian mechanism marked by the end of the needle: the movement which now took place in this mechanism was not greater than those, caused by a slight but quick pressure on the posterior sac as in the experiment D. Thus, the experiments D and F prove that slight but quick pressures on the air-bladder produce greater excursions of the Weberian ossicles, than do strong but slow ones. But, I further venture to maintain that, even if these excursions were equally great, the effects produced on the organ of sense would not be equally perceptible. For it is a well-known fact that organs of sense—and it is of no consequence which is the sense in question—are affected to a greater

degree by slight but quickly intermitting stimuli than by stronger ones following each other at a slower rate.

In all the genera I know of the Characini, and in most of the genera of the Siluroidæ with which I am acquainted by means of autopsy, the malleus is a spring. When so, it may be able to vibrate without any difficulty, but I fail to understand how it may be able to act in the manner suggested by Professors Bridge and Haddon. For a spring offers, comparatively speaking, a considerable resistance against a gradually increasing pressure, but is easily thrown into vibrations by slight but energetic shocks.

For my part, at any rate, I cannot but see that the experiments D and F absolutely prove the incorrectness of the suggestions propounded by Professors Bridge and Haddon on the function of the Weberian ossicles. But, supposing the reader does not agree with me on this point, I take the liberty to adduce what mathematicians call an indirect proof, by showing the incorrect conclusions [1] at which they have arrived when starting from their hypothesis.

1. They declare the walls of the air-bladder in the Siluroidæ to be too thick to be thrown into sound-vibrations, and yet thirty-three years earlier it was proved by Holbrook that the wall of the air-bladder in *Pogonias chromis*, which is so much thicker by far, can be thus set in motion.

2. They declare that the elastic spring apparatus in the genera Doras, &c., and the extrinsic muscles of the Pimelodina are structures related to any method of adjustment to varying hydrostatic pressures, *i.e.* they set forth a hypothesis eighty-four years old, the incorrectness of which had been proved seventeen years earlier (VI.).

[1] Among these I do not even count, that *sans* phrase they attribute to the *saccular* branches of the auditory nerve the capacity of catching perceptions of pressure. If the authors had supposed the semicircular canals to be the organ influenced by the variations of pressure in the air-bladder, this would have appeared less strange to me. That the semicircular canals might be influenced by variations of the pressure in the contents of the air-bladder, and, of consequence, in the perilymph of the cavum sinus imparis, I cannot possibly believe, both because of the foremost entrance to this cavity (in *Cyprinus carpio*) appearing to me entirely filled with the saccus endolymphaticus, and because of the semicircular canals being separated from this cavity by an extremely thick mass of the oily tissue (the arachnoidea).

3. They deny that these structures have anything to do with the production of voluntary sounds—and yet this was proved to be the case fourteen years earlier (II*a*).

4. They declare a fish furnished with an air-bladder in equipoise with the water to resemble the Carthusian diver—and yet this was disproved seventeen years earlier (VI.).

5. They declare that the transmission of sound vibrations from water to the gases contained in the air-bladder [*i.e.* to the gases contained in a small space surrounded on all sides by water] must be accompanied with a considerable loss of intensity —and yet, fifty-five years earlier, by the experiments of Colladon, this was proved not to be the case.

6. They deny the "Siluridæ normales" to be ground-fishes, and yet this was established as a matter of fact for the Siluroidæ in general twenty-two years earlier (XVIII.).

7. They declare (I*a*, 2, p. 151):—"Not a few of the genera of Siluroidæ abnormales inhabit the comparatively *shallow* waters of rapidly flowing mountain streams and torrents, often being at a considerable altitude, and in general habit are not unlike our common English loaches . . . . . Such fishes, when not in motion, probably rest upon or attach themselves to the river bottom, and the uselessness and probable *harmfulness of an air-bladder as a hydrostatic organ under such conditions is no doubt the cause of its degenerative and rudimentary condition.*" And yet Moreau (VI.) had proved, seventeen years earlier, that a fish furnished with an air-bladder acquires the same specific gravity as the water in which it has stayed for some time (and this must, of course, be the case even if it is near the bottom or rests upon it).

8. They declare that the ligament between the Weberian ossicles is "lax, at all events compressible," and that, consequently, "relatively slight incursions or excursions of the anterior process of the tripus [malleus, Web.] will produce no effect on the scaphium [stapes, Web.]." But my experiments D and E prove the contrary. Now, the objection might perhaps be urged against me that, as the authors have only examined specimens kept in spirits, which were not all in the best state of preservation, the ligament of their specimens has, in fact, presented this appearance, the more so as this nature of the

ligament is one of the most important premises of the authors. I shall answer this objection, presently.

9. They declare (I*b*, p. 262):—"In all the Siluridæ normales the air-bladder may be regarded as consisting of two intercommunicating, but physiologically distinct, portions—*a posterior*, represented by the two lateral compartments, which *is indistensible and inelastic*, and always of greater internal capacity; and *an anterior*, which, on the contrary, *is always more or less elastic and expansible*, but of less internal capacity than the former. The distensibility of the anterior chamber, however, is by no means uniform in all directions; on the contrary, and for reasons already given, this portion of the bladder is *absolutely* inexpansible, except laterally at right angles to its antero-posterior axis." And (I*b*, p. 283): "The division of the air-bladder [in the 'Siluridæ normales'] into *a small, elastic, and expansible anterior portion, and a relatively large, inelastic, and inexpansible posterior division*, renders that organ *admirably adapted* for the measurement of the varying volumes of the contained gases, inasmuch as the volumetric variations in the relatively large volume of gas contained in the whole bladder will find their expression almost exclusively in corresponding alterations in the size of the anterior chamber[1] through the expansion or contraction of its lateral walls, which alone are directly connected with the recording Weberian ossicles." But this suggestion is erroneous. On the air-bladder in Doras I wrote ten years ago (II*b*, p. 87): "Regarded as a whole the outer[2] membrane is only very slightly but uniformly elastic, very thick and tough, and very stiff, so that it does not collapse, but is only contracted[3] a little when a fissure, even a long one, is made in it." And with regard to Platystoma and Pseudaroides (p. 92) I used nearly the same words. As to Synodontis and Malapterurus I have had no living specimen, it is true, but the specimens examined had

[1] An almost literal reproduction of Sagemehl's opinion (p. 12) as to the other families of the Ostariophyseæ.

[2] Of course, apart from the ossified parts. The inner membrane, as previously mentioned, is everywhere and always very thin.

[3] It may be remembered that the animals had been hauled up from the bottom of the river only a few minutes ago. Of course, I am here speaking only of the air-bladder when laid open, so that it could not be pressed by the rest of the viscera,

been kept in spirits for a period shorter than six months, and had been put down into the spirits while alive with open bellies, all precautionary measures having been taken, with my anatomical investigations in view, to preserve the viscera. As to both I have stated that the outer membrane "does not collapse." And such is the quality of the inferior and the lateral walls of the air-bladder in its whole extent. Even if the wall of the air-bladder in all the specimens of the "Siluridæ normales" examined by the authors has been in a very bad state of preservation, it is physically impossible—even if they had been kept in spirits from the beginning of this century—that these walls could have undergone such a change that their anterior part had turned elastic, while their posterior part had lost *all* its elasticity. The fact is that, when the authors state the wall of the air-bladder to be of the said quality and the ligament between the Weberian ossicles to be lax, they do so, because this statement is in accordance with their hypothesis. And yet, in their work these conclusions and others do not appear as what they are, *i.e.* conclusions drawn from their preconceived hypothesis, but as premises from which they infer their theory as a conclusion.

In my second paper (III, *Resumé Française*, pp. 135–141) I have shown that parts of the wall of the air-bladder may be ossified and fused together with adjoining skeletal parts; thus the greatest part of the "centra" of the apparently 2nd–4th (the true 2nd–6th) vertebræ in *Platystoma Orbignyanum?* is formed by ossified air-bladder. I have also shown that the round terminal plates of the muscular springs in Doras is formed by (the pleura and) the outer membrane of the air-bladder, which is, in this place, ossified all through, while in Synodontis only the outer strata of the outer membrane is ossified and, together with the ossified pleura, is forming the above-mentioned plates. In Malapterurus, on the contrary, the thin plates are only formed by means of an ossification of the pleura (which is in this place uncommonly thick), as you may be able to follow the outer membrane of the wall of the air-bladder all the way along the posterior concave face of the plates, while in the other genera the plates form part of the wall of the air-bladder, the

fibres of which, either of the whole outer membrane (Doras) or of the outer strata (Synodontis) are an immediate continuation of the plates. Now Professors Bridge and Haddon repeatedly assert (*a.o*, p. 297) that "The bony plates in which the two springs terminate distally are only applied to the anterior wall of the air-bladder, and the fibres of the latter are not directly attached to, or inserted into, the plates at their point of contact, . . . but we have never been able to detect any connection between the latter [the terminal plates] and the component fibres of the tunica externa of the antero-lateral regions of the air-bladder itself." How then is it possible that[1] "Our own investigations enable us to state that Auchenipterus, Oxydoras, *Pangasius djambal*, and *P. Buchanani* resemble in this respect [the nature of the terminal plates] the two last-mentioned genera" [Doras and Synodontis]?

[1] *Ib*, the morphological summary, p. 243.

DESCRIPTION OF A FŒTUS THE SUBJECT OF RETROFLEXION OF THE TRUNK—ECTOPIA VISCERUM AND SPINA BIFIDA; WITH A DISCUSSION AS TO THE CAUSE OF THESE ASSOCIATED ABNORMALITIES.

By THOMAS H. BRYCE, M.A., M.B., *Lecturer on Anatomy, Queen Margaret College, Glasgow University.* (PLATE IX.)

THE specimen which is the subject of this paper was submitted to me for anatomical examination by my friend, Dr Oliphant, Physician to the Glasgow Maternity Hospital, and it is with his concurrence and permission that I publish the description of the monster.

I. DESCRIPTION OF THE FRESH SPECIMEN.

The fœtus was about seven months old. The trunk is acutely retroflexed, and in this position the fœtus measures from the most distant points of the arc it formed 21 cm., but when the bend is reduced as far as possible, the measurement from vertex to heel extends to 30 cm.

The retroflexion has its centre in the lumbar region, and here there is a large spina bifida, the sac of which occupies the whole concavity of the back, and the attitude of the fœtus is such that, the head and legs being extended, the sac of the spina bifida lies wedged between the vertex and the legs, which are adapted to its posterior aspect. The sac measures 12 cm. in its sagittal, 7 cm. in its transverse diameter. In addition to the backward curve there is a slight degree of lateral flexion, so that the apex of the trunk and the interspace between the thighs looks somewhat towards the left.

The ossa innominata are everted so that the symphysis pubis is widely separated, the thighs are rotated at the hip-joints so that the extensor surfaces look outwards, the knees are flexed and the legs crossed. The right foot shows a slight degree of talipes valgus, the left is normal. The arms lie crossed on the chest, and show no imperfection in development. The head,

neck, and thorax are well formed, and the ribs show no distortion from pressure.

The abdominal wall is widely cleft. The cleft begins at a point 2·5 cm. from the subcostal angle, and gradually widens to its point of greatest divergence opposite the ventral ends of the pelvic girdle.

The abdominal viscera lie entirely outside the body wall in a membranous sac continuous with the free edges of the intact portion of the wall, but formed simply by the fœtal membranes. The amnion is everywhere reflected over the viscera, but at the posterior end it is cleft, and passes as two diverging folds to the edge of the placenta, and again converge towards the centre of the placental disc, thus leaving between them a lozenge-shaped space. The amnion had at birth been partially torn away from the anterior part of the cleft abdominal wall.

The figures show the placenta and membranes suspended from the fœtus, but it should be noticed that when the membranes were intact, the fœtal surface of the placenta must have lain in close proximity to the lower limbs, and the allantoic stalk directed backwards from the hind end of the fœtus. From the centre of the placenta run in close company two vessels, firmly bound down to the surface of the organ. They part from each other at its edge, and, entering the folds mentioned above, run under cover of them to the abdominal wall, under which they disappear.

Between the folds, and overlapped by them, is an oval area, the upper part of which is bright red in colour and evidently covered by mucous membrane, the lower half directly continuous in substance with the upper, is thin and membranous. The red area measures from base to apex 3 cm., the base line is 2·5 cm., and its apex is overlapped to the extent of 1 cm. by a fold of membrane continuous with the skin above. In the middle line lies an elevated column, firm and fleshy in substance, and attached along its whole base. Immediately below this, but separated from it by a tiny yellow nodule with a depressed centre, is a vertical slit 9 mm. long, which opens into the space containing the viscera. On the lateral parts, also overlapped by the membranous fold, there are two slight ridges, on which are placed two pin-point apertures, the openings of the ureters.

Above this area, between the thighs, there is a triradiate sulcus, indicating the situation of the approximated ischia; and below this, on the skin surface, the anal pit, into which a director passed to the extent of 1 cm. in an oblique direction towards the mesial elevation in the red area.

On each side, closely related to the bony projections corresponding to the pubic bones, there is a cutaneous fold or tag, apparently representing the genital fold. There is no sign of any external organs of generation recognisable as such.

II. Dissection of Specimen.

As described above, the viscera lay in a membranous sac continuous with the abdominal walls.

The liver is of normal size. Two-thirds of its bulk project beyond the incomplete abdominal wall. The anterior border is thick and rounded, the posterior thin; all the normal lobes are represented, and the right and left are separated on the upper aspect by a deep fissure, which leaves only a narrow bridge of liver substance connecting the lobes superficially at the posterior border. The umbilical vein courses along the free edge of the abdominal wall on the left side, and reaching the liver in a fold of peritoneum near its posterior border, it enters the fissure from above. After a short course in the fissure it breaks up into a large number of branches, one of which larger than the others was traced into a large main branch of the portal vein.

The gall-bladder and duct show their normal relations. The stomach had turned over on its right side, so that there is a duodenal loop with normal relations to liver and kidney. The omental fold had not developed, and the spleen has no parietal connections. It is elongated in form, and lies in the mesogaster adapted to the greater curvature of the stomach. The pancreas lies in its normal situation relative to the stomach, behind the small "lesser bag" of the peritoneum.

Beyond the duodenum the intestine has retained its primitive mid-dorsal mesentery throughout its entire length. It is closely coiled, after the manner of the small intestine; there is no colonic loop, no cæcum nor vermiform appendix, and no trace of the vitelline stalk. When uncoiled, by detaching the mesentery, it measured 3 feet 6 inches; the terminal 6 inches was of con-

siderably larger calibre, but the muscular coat formed a continuous covering as in the small intestine.

It ends by an oblique opening common to it and a sac presently to be described. The upper end of opening is continuous with the upper end of the vertical slit in the mucous membrane covered area. The rest of the circumference, composed of very thin lips, is not attached to the edges of the slit, but they look as if they may have been stripped apart, and there was a small coagulum of blood to strengthen this idea, but it is impossible to speak with certainty about the point. Comparison with Vrolik's[1] very parallel case tends to support this supposition. In it the intestine and a blind sac ended together in a depression upon a similar red area—cloaca, he calls it—by two separate openings, through which the mucous membrane was reflected.

Above the intestine there is a sac figured in fig. 4. It is 3·2 cm. long, 1·3 cm. broad, and 2·3 deep. The convex border is irregular, as it were faintly lobed, folded, or constricted at intervals. To it the mesentery is attached, and it carries a large number of small vessels to be distributed over the outer surface of the sac. The walls are thin, and there are no longitudinal bands; the mucous membrane forms a thick lining, and is thrown into prominent folds, which cause the folded appearance of the outer surface. Over the attached surface or base the mucous membrane has a reticular appearance, like that of the gall-bladder. The base or ventral border, directed in the intrauterine position backwards, is firmly attached to the middle line of the triangular flap, bearing on its outer surface the red mucous membrane covered area.

From the base, a little below the termination of its free converse border, a fibrous cord passed upwards to be attached to the tip of the vertebral column—to the cartilaginous nodule representing the coccyx.

The kidneys are subequal in size, the right being the larger, and both are irregularly lobed; neither is hydronephrotic, as in some recorded cases. They are surmounted by large adrenals, and the left is pierced by a vessel which may be taken as representing the common iliac. The ureters pass down on each side

[1] *Tab. ad. illustrand. Embryogen.* 1849. Pls. 21 and 22.

of the base or attached border of the sac, and open on to the surface of the red area as described.

On the ventral aspect of the kidneys lie genital glands: the right lies free; the left slightly under cover of the abdominal wall, and of much smaller size.

Behind the right gland, towards its outer side, there is a structure closely applied to it, which has the appearance of the epididymis. Leading from the lower end of this are two delicate cords: one, the duct, could be traced closely applied to the ureter for some distance, but it was lost as the ureter neared its termination. The other cord passes transversely outwards and ends in the subcutaneous fascia in the neighbourhood of the pubis and the cutaneous fold representing the genital fold, and is evidently the gubernaculum.

A microscopic examination of the genital gland proved it to be the testis. The sections showed the commencing corpus of Highmore and the seminal tubes in the body of the gland, and behind a mass of tubules, with at one part the remains of the Wolffian body.

There is no trace of Müllerian ducts.

The anal pit, as already mentioned, is 1·2 cm. in depth. When the skin of the perineum was removed, the tube could be readily isolated from the fascia and irregular muscular bundles passing down to it from the ischia. This anal tube is directly continued into a fibrous cord, which passes under the elevated middle portion of the red area, and thinning off, ends between it and the sac. Tube and cord run parallel to the upper part of the base of the sac, and its fibrous cord passing to the coccyx.

Under the mucous membrane, covering the median elevation, there is a fleshy column about 2 mm. in diameter. This divides above into two; but the horns become so rapidly thin and delicate that I could not with sufficient certainty distinguish them from the fascia, or trace them to their destination. Microscopic examination showed that this column was provided with a dense fibrous outer coat, and that the centre was made up of an irregular, loose reticular tissue, with many wavy fibres, and in this lay several blood-vessels in cross section. It showed no epithelial lining, and was therefore not a tube or duct, but closely corresponded to the arrangement of erectile tissue.

The proximal part of the red area, as far as the openings of the ureters and tip of the mesial column, has a thicker floor than the distal part in which the opening is placed.

The diaphragm is represented only by a membranous septum forming the floor of the pericardium, and extending laterally to the costal margin.

The heart and lungs are normal.

Circulation.—The abdominal aorta and vena cava inferior are highly irregular in the distribution of their branches, many of which cannot be said to correspond with any normal branches. The main feature is the direct continuation of the aorta into the right allantoic artery, which we saw running to the placenta in the right amniotic fold. The left artery has disappeared, while, on the other hand, only the left vein has persisted, occupying the left fold, and passing to the liver as above described. The general distribution of the vessels will be understood by reference to the schema (fig. 5). An interesting point may be noted as to the arteries to the limbs. On the left side a branch, which may be called the common iliac, after passing through the kidney substance, gives off femoral and internal iliac branches. The femoral is the definitive artery of the extremity, while, on the right side, the corresponding branch reaches only the lower third of the thigh, and the main artery of the limb is the primitive sciatic.

The muscular system shows nothing specially noteworthy. Owing to the distortion of the pelvic girdle, the direction of the muscles is greatly altered. Thus the psoas is almost transverse in direction, passing backwards and outwards. The three muscular layers of the abdominal wall are represented, but of small extent, owing to the approximation of the crest of the ilium with the costal margin. The recti occupy the free edges of the abdominal wall, and have their usual sheaths.

The *spina bifida* involves the laminæ from the 9th dorsal to the end of the vertebral column. In the lumbar region they are present, but forced apart. In the sacral region the neural arches are entirely absent. The sac involves only dura mater, and it communicates with the spinal canal by a comparatively narrow neck opposite the last two lumbar and the first sacral vertebræ.

The spinal column has a double curve. It is bent backwards at an angle of 110°, the centre of the curve being placed between the last dorsal and first lumbar vertebra. The lateral curve has its centre slightly higher up, making an angle of about 150°, the convexity towards the right. There is also a slight degree of torsion. The number of vertebræ is irregular: —$C_7D_{11}L_4$Sacral$_2$Pseudo-sacral$_3$, and a terminal cartilaginous nodule, to which is attached the fibrous cord from the sac before described.[1]

The pelvic girdle has undergone a double rotation. The ventral ends have been rotated outwards, so that the pubic symphysis is widely parted, the acetabula look almost directly backwards, and the ischia are carried towards each other. The second rotation has taken place at the sacro-iliac joint, at right angles to the first, so that the ischia are carried back behind the sacrum.

The left ilium shows two foramina above and behind the acetabulum, through which pass two roots of the great sciatic nerve.

III. Discussion as to the Nature and Causes of the Series of Abnormalities.

The departure from the normal structure and relation of parts consists essentially in (1) a retroflexion of the trunk associated with the formation of a spina bifida; (2) a cleft body-wall, with the point of greatest divergence at the ventral ends of the pelvic girdle; (3) a defective development of the pelvic organs and posterior part of the intestine; (4) absence of an umbilical cord, associated with the drawing backwards of the viscera and approximation of the hind end of the fœtus to the placental site.

Such cases are rare,[2] but the association of these abnormalities

[1] There are thus two vertebral bodies absent at the point of flexion.

[2] For similar cases see *Vrolik*, Tab. ad illustr. Embryogen, 1849, Taf. 21 and 22. *Ahlfeld*, Missbild. des Mensch., 1882, plates 33, 34, 35 (collected cases). *Förster*, Misbild. des Mensch., pl. 22. *Simpson*, Edin. Med. Journ. 1882 (with reference to 14 collected cases). *Duncan* and *Hurry*, Obstet. Trans. London, 1884. *Lockwood*, do., 1887, vol. xxix. *Dakin*, do., vol. xxxii. *Routh*, do., vol. xxxiv. *Remfry*, do., vol. xxxvi. *Giles*, do., vol. xxxvi. *Leith Napier*, do., xxxvi.

together is well recognised, though the degree of departure from the normal standard may vary. Retroflexion may occur without ectopia of the viscera, and *vice versa*, but the former is extremely rare, and generally the two are associated with each other and with defective development of the pelvic organs. This specimen may be taken as representing in an exceptionally perfect way the highest degree of the condition. A special feature in such cases is the maldevelopment of the umbilical cord. It is generally absent or very short, and this fact has led that structure to be credited with the causation of both retroflexion and ectopia.

The most elaborate attempt to explain the whole sequence that I know is Ahlfeld's.[1] He picks out the yolk stalk as the *origo mali*. He supposes that the traction on the yolk stalk, produced by a sudden increase in amniotic fluid, draws the intestine away from the vertebral column, and thus hinders the abdominal walls from uniting. If the strain is at right angles to the vertebral column a ventral hernia results. If the yolk sac be placed more to the hind end of the embryo it will draw the intestine backwards towards the perineum, and carry before it the allantois. The union of these prevents the closure of all parts, which develop by meeting together in the middle line, and thus the whole under part of the body and perineum remain split.

The allantois, which he supposes a large sac, remaining unconnected with the exterior, fills with excretion, thins out and bursts. Its front wall is thus lost,—the hinder wall alone remains, covered with mucous membrane, and a "blasenspalte" is produced. The intestine shares in this, and an unnatural anus lies between the two halves of the bladder, generally connecting the ilium with the bladder, either at the end or at the attachment of the ductus. A case in which there is no opening into the intestine he explains by supposing the separation of the yolk stalk to occur after the closure of the bowel; a small opening common to ilium and cæcum he attributes to a separation just before closure, and a widely gaping gut lying open or prolapsed between the halves of the bladder to a separation at a still earlier date. He supposes the disappearance of portions of

[1] *Missbild. des Mensch.*, abs. ii. pp. 204 *et seq.*

the intestine to be due to their being torn off with the yolk stalk or obliterated. Portions of the gut may remain blind, or open by a second unnatural anus behind the first into the bladder. The mesentery is lengthened by the downward displacement of the intestine; other structures must pass in to fill up the space; and he even attributes to his theoretical "zug" the bending of the vertebral column, seen in most of such cases.

Drs Duncan and Hurry,[1] referring specially to the retroflexion, discard the view of Vrolik,[2] that the weight of the viscera is the cause of the attitude, and partially accept Houel's[3] view, that the fault is in the length of the cord, adding, however, that the attitude is impressed on the fœtus by the shape of the uterus.

Dr Dakin,[4] in describing a case (1890), attributes the general train of abnormalities to imperfect development of the hind-gut and its processes. His view is that the allantoic stalk has remained short, and kept the ventral aspect of the fœtus anchored to the placental site; that this has caused the ectopia, while the attitude is due to the moulding of the fœtus to the uterine wall. This view has been adopted by those who have followed Dr Dakin in describing cases of this kind. A committee of the Obstetrical Society of Paris (1891),[5] in reporting on a case showing many of the features of my specimen, refer the visceral defects to the cloaca interna, but of this paper I have only been able to obtain a short digest.

My specimen certainly shows that the root of the matter lies in the "hind-gut and its processes," as Dr Dakin argues, but the retroflexion of the trunk, I think, cannot be regarded as secondary.

I think I may fairly conclude that the anatomical details enumerated above, indicate that the attitude of the fœtus was impressed on it at a very early date, and that the cause of the bend must therefore be sought for in the fœtus itself, and not in its accessory parts, or in its relations to the uterus. Such agents as the weight of the viscera (Vrolik), the absence of the supporting abdominal wall (Förster), the traction of the vitelline duct

[1] *Obstet. Trans. London*, 1884, vol. xxv.
[2] *Tab. ad illust. Embryogen*, 1849, plates 21 and 22.
[3] Houel, *Soc. de Biologie*, 1858, iv. p. 55.
[4] *Obstet. Trans. London*, vol. xxxii., 1890.
[5] Hamaide, *Bull. et Mem. de la Soc. Obstet. et Gynec. Paris*, 1891.

(Ahlfeld), shortness of the cord (Houel), or moulding to the egg-shaped cavity of the uterus (Duncan and Hurry), would certainly act as secondary causes, maintaining or aggravating an early defective attitude, established before they could operate, and would determine the position of the fœtus in utero and its consequent presentation, but cannot be regarded as primary.

Dr Remfry,[1] who accepts the view that the attitude is secondary, says, "absence of vertebræ will produce a flexion backwards at the deficient point, the vertebræ above and below tending to approximate." I do not think this follows. The vertebral bodies in my case were closely applied to one another at the bend, and I think it is more reasonable to suppose that this absence of vertebræ has been due to the primary malposition of the vertebral axis, which would necessarily interfere with the secondary segmentation, which results in the formation of the vertebral bodies. If this is so, it places the primary defect far back in the developmental history.

In very young embryos, from the 13th to the 18th day, in Müller's, Kollmann's, Costes', and His' embryos, E, S.R, L.E, Sch, and B.B, there is a marked retroflexion of the trunk (fig. 6). Now, whether this remarkable feature be a normal one or not, it is commonly—though there are too few early embryos, perhaps, to say universally—present at this stage, while in older embryos it has disappeared to give place to the ordinary ventral curvation, and at all later stages it is only rarely seen, and as a rule in association with such abnormalities as seen in the present specimen.

His suggests[2] that this bend may be due to a disproportion between the amnion and the embryo; and Dr Duncan's case,[3] in which a retroflexion was caused by amniotic bands—or rather, I should say, maintained—is interesting in the light of this suggestion, that the cause lies in the amnion. In this case there was no further abnormality of the viscera, but usually the bend is associated with ectopia and maldevelopment of the hind-gut and pelvic organs.

[1] Remfry, *Obstet. Trans. London*, 1894, vol. xxxvi.

[2] Marshall, *Vert. Embryology*, 1892, on whose authority I make this statement, as I have not been able to put my finger on the passage in the original.

[3] Duncan, *loc. cit.*

I would suggest, therefore, that, in such cases, the early retroflexion, normal or abnormal, due to some cause within the fœtus itself at this stage, has been maintained by the persistence of the original distorting agent, or by an associated early defect in the abdominal or allantoic stalk, combined with a defective development of the hind-gut and allantois, preventing the incurving of the tail end of the embryo such as normally occurs.

While the features of the case clearly point to the source of the abnormalities lying in the hind-gut, it is by no means easy to trace in what the departure from the normal development consists, or to identify the parts with their normal prototypes.

The umbilical cord, properly so called, is evidently absent, and the broad flap bearing on its upper part the mucous membrane, and uncovered by amnion, must be the abdominal or allantoic stalk. It has been noticed that this stalk in the intra-uterine position was directed backwards from the ventral aspect of the hind end of the fœtus, and comparison with fig. vi. at once suggests that its primitive relations have been maintained. Instead of becoming gradually turned forwards to the ventral aspect, and lengthening out to form the umbilical cord, the allantoic stalk has remained short and broad, and has kept the hind end of the fœtus close to the placental site. Now the figure of the early embryo further shows that the stalk is applied to the hind wall of the yolk sac, and that of necessity, if it was not turned round, and if the incurving of the tail did not take place, as the embryo increased in size, the formation of the posterior part of the intestine would be interfered with, and a traction would be exerted towards the hind end of the fœtus, which would draw the developing intestine backwards,—would, in fact, do for it what Ahlfeld attributes to the traction of the yolk stalk. In the shortness of the stalk and the approximation of the hind end of the fœtus to the uterus, or rather the chorion, a *point d'appui* is provided, which cannot be predicated of the yolk stalk, which has so unimportant a share in the formation of the umbilical cord.

If we suppose that the primary cause of the maldevelopment of the intestine be thus early in operation, there is no need to account for the absence of any part of the intestine by supposing

it to be obliterated or torn away by the traction on the yolk stalk, because the distinction into large and small intestine is only established after a primitive uniform gut has been formed.

Moreover, the absence of the folding in of the tail end of the embryo, which is an important factor in the formation of the hind-gut, seems a more probable explanation of the failure of the gut to close than Ahlfeld's, if we accept the theory that such a failure has taken place.

According to Ahlfeld's hypothesis, the sac would represent the abnormal colon, the opening into the mucous membrane covered area an abnormal anus, common to the two portions of the gut. This anus opens into the bladder, the ventral wall of which has burst, breaking through the amnion at the same time, and thus we have a "blasenspalte" and a "geschlectspalte."

Now, if we considered that the three openings had remained free, the only explanation under this hypothesis would be that they represent, the one the open neck of the urachus, the other two the open neck of the yolk sac—the colon, or rather the whole of the intestine behind the vitelline duct, being imperfectly closed off from the yolk sac.

If the openings were continuous as in all other similar cases, then the only possible explanation of an opening into the median unpaired allantois would be, that an artificial opening of the nature of an internal hernia had formed. The cases Ahlfeld gives in plate xiii. figs. 2, 3*a*, and 13, in which the mucous membrane of the bowel is represented as lying open between the separated halves of the bladder, he explains by supposing the bowel to have remained split and prolapsed between the halves of the bladder.

It seems impossible to reconcile these explanations with what is now known of the development of these parts.

The allantoic or abdominal stalk[1] is a direct continuation of the posterior end of the embryo, and is formed before the allantois proper, which is a projection, a portion of the gut, derived by splitting off from the yolk sac like the rest of the intestine.[2] The hind-gut enlarges into a considerable sac-like dilatation,

[1] His, *Anat. Mensch. Embryonen*, iii. pp. 12 *et seq.* and 222 *et seq.* Lockwood, *Phil. Trans.*, vol. clxxix., 1888.

[2] His, *loc. cit.*

called by His the bursa pelvis or cloaca interna. From the ventral end of this the allantoic diverticulum is projected into the abdominal stalk. Later the cloaca interna receives the ureters and the Wolffian ducts, at first by a common opening, which later becomes subdivided, so that they open separately. It then becomes subdivided into a dorsal or rectal and a ventral or uro-genital tube, which now receives the ureters and Wolffian ducts, and is continued directly forwards into the allantoic tube. The division is effected by a septum [1] which grows from the angle between the allantois and intestine, and reaching the exterior, subdivides the proctodeal invagination into anal and uro-genital openings, forming the perineum either alone or by further cutaneous folds. Further, it is said[2] that the septum is formed by the union in the middle line of two lateral folds. Thus the whole of the urethra in the female, and the prostatic and membranous portions in the male, as well as the trigone of the bladder, are derived from the division of the cloaca interna, the original opening of the allantois from the primitive tube being represented by the borders of the trigone of the bladder.[3]

Cases of anus vesicalis must, therefore, be explained by imperfection in the formation of the septum, and not taken as representing atresia of the original allantoic diverticulum. A case of Förster's [4] (Taf. xxiii. fig. 9), in which a small opening passed from the rectum to the trigone of the bladder, supplies a typical illustration. The bladder and rectum were both unconnected with the proctodæum, but were otherwise normal except that the rectum was dilated into a sac-like tube. The opening must have been due to the persistence of the loop between the two tubes, which is normally obliterated by the septum reaching the exterior, by the fusion of the hypoblastic cells covering the apex of the septum with the cells of the ectoblastic thickening, called by Tourneux [5] the "bouchon perinéal." Extreme cases such as those figured by Ahlfeld, where the bowel lies between the two

[1] Tourneux, *Jour. de l'Anatomie*, vols. xxiv. and xxv. Retterer, *Jour. de l'Anatomie*, vol. xxviii. Nagel, *Arch. für Micr. Anat.*, 1892. *Schäfer in Quain*, vol. i. part i., 1890.

[2] Marshall, *Vertebrate Embryology*, 1892.

[3] Macalister, *Text-book of Human Anatomy*, p. 448.

[4] *Missbild. des Mensch.*

[5] Tourneux, *loc. cit.*

separated parts of the bladder, might also find an explanation in the failure of the lateral folds to unite in the middle line to form the septum—for only the part of the bladder derived from the cloaca interna could be thus divided—unless we imagine some internal hernia. But whether such an explanation would supply a key to this maldevelopment it is impossible to say without the actual study of such a specimen.

A case described by Dr Routh [1] supplies a link here. In it there was retroflexion and ectopia, and the intestine ended in a large transverse sac, which had no normal anal opening, but passed by a narrow mouth on to a mucous membrane covered area, as in my specimen. This opening, however, had the mouths of the ureters on each side of it. A committee of the Obstetrical Society took the view that the sac represented the dilated uro-genital sinus (or proximal part of the allantois), and the mucous membrane covered area the extroverted bladder (or distal part of the allantois). In the light of the account given above of the development of the parts, I would suggest an alternative explanation,—that the sac is an abnormal dilatation of the cloaca interna, with defective development of the uro-genital passage from its imperfect division. The rudimentary Wolffian ducts opened into the sac, thus retaining their primitive connections.

In the present case the anus vesicalis cannot quite correspond with that seen in those cases. The red mucous membrane covered area must be taken as representing the whole genito-urinary passage, the open allantois, genito-urinary division of the cloaca interna, and the cloaca externa. The part receiving the ureters was thicker and fixed to the sac; the distal part, in which lay the slit, was free, and attached only to the opening of the intestine. This anus vesicalis is in the allantoic part of the bladder. If the sac represent the whole intestine behind the vitelline duct, then Ahlfeld's hypothesis as to the imperfect closure of the bowel must hold; but how can we explain the relations to it of the uro-genital passage, the Wolffian ducts, or the blind Müllerian ducts in Vrolik's [2] case? or how are we to reconcile the condition described by Dr Routh?

Although, perhaps, the facts of this case, even when compared with recorded cases of a similar kind, may hardly seem to justify

[1] *Obstet. Trans. London*, 1892. [2] Vrolik, *loc. cit.*

any further hypothesis than that to be stated in my second and third propositions, I venture to suggest that the sac represents not the whole intestine behind the yolk stalk, but the much-dilated "bursa pelvis"; that its ventral end gives off the allantoic diverticulum, which has failed to unite in the mid-ventral line,[1] so that it lies open, and continuous with the defective urinary sinus; and further, that the presence of this large abnormal pelvic sac has mechanically interfered with the closure of the somatic wall. It will be remembered that the cleft was at its widest opposite the pelvis.

The anal diverticulum has failed to meet the rectal portion of the cloaca interna, but the perineum has been formed, and separates the anal tube from the open urinary tube in front, so that we must imagine an attempt at division of the enlarged cloaca interna, which has resulted in the formation of the perineum, and the defective urinary passage.

I am unable to identify the fibrous cord passing from the anal tube with any normal structure. If one took it for an obliterated rectal tube, running down towards the lower end of the sac, then one would require to presuppose that the post-anal cul-de-sac had persisted and been involved in the dilatation of the rest of the bursa.

We saw that under the mucous membrane of that part of the red area which we have referred to the cloaca externa, there was a structure which was composed of tissue so resembling erectile tissue, that it was to be regarded as a rudimentary clitero-penis, derived from a displaced genital papilla, and reference to Vrolik's case and one in Ahlfeld's *Atlas* (plate xxxv. fig. 18) strengthens the idea. It is difficult to account for this separation of the genital papilla from the genital folds, derived from the somatopleure; and though I think it may be susceptible of explanation in the light of the development of the genital papilla,[2] I am not now prepared to form conclusions about it.

We have, then, in this specimen a remarkable series of abnormalities, so far removed in the structure and relationship of parts from the normal standard, that we can only in general

[1] His, *loc. cit.*

[2] Nagel, *loc. cit.*, and *Arch. für Micros. Anat.*, voi. xxxiv. Tourneux, *loc. cit.*, and Retherer, *loc. cit.*

terms indicate with any degree of certainty where the divergence from the normal development had its origin. I think, however, I may safely suggest, by way of accounting for the whole train of defects, the following hypothetical propositions, for which I believe I have shown there is some basis in fact:—

I. The retroflexion of the trunk is primary, and expresses the maintenance of a very early attitude which is due to some cause, normal or abnormal, within the fœtus itself.

II. The allantoic stalk has failed to turn round to the ventral aspect and lengthen out to form the umbilical cord.

III. There has been a very early and profound maldevelopment of the hind-gut and its projection into the allantois, which, along with No. II., has resulted in very defective development of the whole pelvic organs.

IV. In consequence of the presence of a pelvic sac drawn backwards by the failure of the allantoic stalk to lengthen out, the somatic walls have been prevented from uniting in the mid-ventral line.

V. In consequence of the bend of the vertebral column, the development of the neural arches has been mechanically interfered with, and a spina bifida formed.

VI. The cause of the maintenance of the early attitude is to be found in the early defective development of the allantoic stalk and hind-gut, which has interfered with the incurving of the tail end of the embryo.

The association of defects of the neural and alimentary canals is well recognised, and is attributed to their intimate relationship;[1] and if my hypothesis be correct, it is interesting to note that, according to it, the hind ends of the two canals are both affected by a parallel pathological process.

[1] Bland Sutton, *Trans. Path. Soc.*, 1888.

THE POPLITEUS MUSCLE. By HUBERT HIGGINS,

Demonstrator of Anatomy, Cambridge University.

IN the course of my investigations on the knee-joint, I found that the popliteus was invariably connected with certain structures in the joint. I propose to enumerate its attachments, and to endeavour to show that it plays an important part in the mechanism of the joint.

Origin (1) By short, strong tendinous and muscular fibres from the internal border of the tibia, under the internal lateral ligament.

„ (2) By muscular fibres from the soleal line.

„ (3) By a few scattered muscular fibres from the supra-soleal space between and from the bundles of the periosteal ligaments. The interstices contain some loose cellular tissue and fat, so that the muscle can be easily separated from the bone.

„ (4) From the border of the internal tuberosity bounding the supra-soleal space above.

„ (5) In rather more than 80 per cent. of cases a loosely attached rounded bundle of muscular fibres arises from the fibula immediately above the peroneo-tibial band, between the soleus and the tibialis posticus.

From this origin the fibres converge to immediately behind and internal to the head of the fibula; all or a varying proportion of the muscle fibres form a tendon, ovoid on section, which grooves the tibia over the cartilage-covered fibres of the posterior superior tibio fibular ligament, behind the external articular surface. After grooving the external semilunar cartilage it grooves the femur at the hinder part of the articular surface of the external condyle, and is inserted into a depression immediately below and anterior to that for the long external lateral ligament.

The tendon is connected with the following structures:—(1) The tibia. (2) The fibula. (3) The ligamentum posticum Winslowii. (4) The posterior crucial ligament. (5) Wrisberg's ligament. (6) The true capsule. (7) The external semilunar cartilage.

(1) *The Tibia.*

Among the deep set of fibular fibres on the inferior and deep surface of the tendon there are occasionally a few fibres blended with the coronary ligament and attached to the tibia.

(2) *The Fibula.*

Adherent to the superficial and deep surface of the tendon are two strong and distinct bands of fibres, passing from the fibula to one or all the following structures:—the posterior crucial ligament, Wrisberg's ligament, the posterior cornu of the external semilunar cartilage, or with the adjacent ligamentum posticum Winslowii directly or through some dense connective tissue.

(3) *Ligamentum Posticum Winslowii.*

In over 60 per cent. of specimens, tendinous fibres from the popliteus contribute to the formation of the ligament; they may even form the attachment of more than half the muscle, the thick accessory capsule being attached just beneath and on the inner side of the outer head of the gastrocnemius. In those specimens in which the muscle is not attached to the ligament the two are connected to it by some dense connective tissue.

(4 and 5) *The Posterior Crucial and Wrisberg's Ligament.*

There are in most specimens some fibres contributing to the oblique portion of the posterior crucial, derived from—

(A) The tendon of the popliteus; or

(B) That part which is occasionally attached to the ligamentum posticum Winslowii.

The following are the chief dispositions of these fibres:—

(i.) They may be mixed with some irregularly disposed fibres on the outside of the posterior crucial, and attached to it immediately under the ligamentum posticum Winslowii.

(ii.) They may run horizontally into the oblique portion being very tightly bound down at the angle of junction, and then continued upwards and inwards with the oblique crucial fibres.

(iii.) They are usually connected with the fibres derived from the short external lateral ligament.

(iv.) In some specimens Wrisberg's ligament is found to be connected with the fibres of the popliteal tendon, and frequently with those which are attached to the fibula.

(v.) In one specimen some fibres which, from their femoral attachment, apparently represent Wrisberg's ligament, are only connected below with the tendon of the popliteus, to which they run at right angles.[1]

The following are the commonest connections of the muscle:—

1. Directly, by means of fibres continued from the tendon, either posterior to or anterior to (uncommon) the popliteal groove on the cartilage.

2. Certain horizontally-disposed fibres, passing to the posterior crucial ligament from the popliteus, are intimately connected with the posterior cornu.

3. There may be a strong portion of the capsule connected with the superficial part of the tendon, and firmly connected with the cartilage anterior to the groove.

4. The posterior cornu, the popliteus, and the external semilunar may be connected by some dense irregularly arranged fibres which fill up the interval between them.

The conspicuous features in the attachment of the muscle are, that its main origin is from the most distant point on the tibia, the internal border, its intimate and constant connection with the posterior crucial ligament and the external semilunar cartilage, and the limitation of the excursion of its tendon imposed on it by the short, strong fibular bands. I think that the muscle either causes the tibia to rotate inwards when acting from the fixed femur, that it aids the outward rotation of the femur with the cartilage on the tibia, acting from the fixed

[1] I have postponed the relations of the tendon to the true capsule for consideration in a future paper.

tibia when the foot is resting on the ground. The value of the connection with the cartilage is that it secures its presence at the hinder part of the tibial articular surface during the completion of flexion. When the tibia rotates, the tense tendon retains the cartilage and prevents it being carried forwards; when the femur rotates, the cartilage is dragged with it. This rotation of the femur or tibia is for the purpose of compensating for the deficiency of about 2 cm. in the antero-posterior surface measurement of the external condyle, so that contraction through the space permitted by the fibular bands would be sufficient for the purpose.

The following considerations tend to show that rotation takes place either immediately before, after, or during the period that the leg is at right angles to the thigh,—

1. Owing to the attachment of the tendon being more than 2 cm. from the hindmost part of the external condyle, and the backward projection of the condyle, contraction at any period until half-way to the right angle is reached would only result in the compression of the articular extremities.

2. The ligaments are most relaxed at this period of contraction.

3. The femoral groove, which is in all probability caused by the tendon in its contraction, is directed upwards and backwards, and is not in the same direction as the tendon till the femur is at right angles to the tibia.

4. When sitting with the foot resting on the ground before and after the leg is at right angles to the thigh, the tibia can be slightly rotated and pushed forwards and outwards; the greatest movement takes place when the angle is just less than a right angle. Though during this movement there is contraction of the extensor and flexor muscles of the leg, the popliteus can be distinctly felt to contract.

5. The popliteus contracts, and its pressure produces the groove for its tendon, the direction being a little below the horizontal position in semiflexion, thus indicating that the muscle contracts during semiflexion.

After the rotation has taken place, the fibular bands would prevent any further action of the muscle; and if, as is probable, it is maintained in a state of contraction up till complete flexion,

it would be of service in keeping the external semilunar cartilage fixed, and to prevent it being pushed forward at the completion of flexion.

In those specimens where an unusually large proportion of the muscle is attached to the ligamentum posticum Winslowii, the direction of its action and the limitation of its excursion are provided for by strong oblique fibres running from the attachment of the muscle to the internal condyle.

Possibly the fibular origin is homologous to the coronoid head of the pronator radii teres.

In (complete) flexion the cartilages are wedged between the tibia and the hindmost parts of the articular surfaces, producing more or less distinct grooves, both on the external and internal articular surfaces.

THE GENICULATE ARTICULAR SURFACES OF THE FEMUR AND TIBIA.

By HUBERT HIGGINS, *Demonstrator of Anatomy, Cambridge University.* (PLATE X.)

IN the course of some researches on the knee-joint, I found it necessary to investigate the variations in the conformation of the articular surfaces, in order to elucidate some points in the mechanism of the joint. In this paper I have described such variations in the cases of 40 femurs and 40 tibias.

PART I.—THE FEMUR.

The femoral articular surface is divided into three distinct areas :—

(1) The trochlea.
(2) The internal articular surface.
(3) The external articular surface.

I. *The Trochlea.*—Its lower boundaries from within outwards are—(1) the peripheral angle between it and the internal articular surface (see below); (2) the coronal portion of the internal semilunar depression; (3) a slight smooth elevation separating it from (4) the depression for the antero-external elevation of the internal articular surface of the tibia; (5) the latter is sometimes continuous with the grooved depression for the anterior crucial ligament, which is continuous with the central depressed part of the trochlea; (6) the forepart of the external spinal depression; and (7) an elevation separating it from (8) the depression for the external semilunar cartilage.

On the upper part of the outer angle of the trochlea the articular surface is usually on the same plane as the adjacent non-articular surface for about 1·80 cm. In 50 per cent. of cases there is a transverse groove a few lines beyond the articular surface (1·80 × ·45). It is uncommon to find the articular surface bounded by a ridge as on the rest of the surface. This is probably produced by the patella in extension.

The Internal Articular Surface.—On this surface are seen depressions for the following structures :—

(1) The internal semilunar cartilage.
(2) The antero-internal elevation of the internal articular surface of the tibia.
(3) The internal spine of the tibia.
(4) The internal semilunar cartilage on the hindmost part of the articular surface. And on its peripheral border there is usually an angular depression separating it from the trochlea, and a smooth, shallow depression for the internal lateral ligament.

The Internal Semilunar Depression.—This is a smooth curved groove of varying depth, definition, and length. It consists of an anterior coronal portion, and is joined in a curved manner to a peripheral sagitally-disposed part.

The coronal portion is curved, and is about 1·60 cm. long. It may be a well-marked groove, or only a slight depression. The sagittal groove is separated from the periphery of the articular surface by an elevation, and varies between ·30 cm. and 2·80 cm. in length (average 1·30). It is never so deep as the former, and may, in rare cases, be scarcely perceptible.

Depression for the Antero-Internal Elevation of the Internal Articular Surface.—This is a shallow but usually well-defined depression (indistinct in 20 per cent.), situated immediately anterior and internal to the antero-internal border of the non-articular surface. It is separated by a slight elevation from the external extremity of the internal semilunar depression, and passes imperceptibly into the internal spinal groove. It is also not infrequently continuous with the depression for the anterior crucial.

Internal Spinal Depression.—The internal tibial spine causes a well-marked depression. It is usually most distinct at the angle separating the internal and antero-internal borders of the non-articular surfaces, on which it generally encroaches. There are two chief varieties.

(1) In this variety a groove is found (·40 × 2·00 cm.), bounded mesially by a border which is in some cases sharp (15 per cent.). in others more or less rounded (20 per cent.). The external

limiting border is usually nearly straight, but it may be concave (25 per cent.).

(2) In this variety the border of the articular surface presents a smooth rounded concavity about 1·70 in length (30 per cent.).

In these specimens there is a greater distance separating the articular surfaces.

Posterior Internal Semilunar Depression.—The internal articular surface is continued farther back on its external half; unlike the corresponding part of the external articular surface which terminates abruptly, it slopes gradually on to the shaft. On this sloping surface is found a shallow groove, which is formed by the pressure of the posterior part of the internal semilunar cartilage in extreme flexion. It is well marked in about 50 per cent.

The Internal Periphery of the Internal Articular Surface and Trochlea presents two points of interest, separated from each other by an interval of about 3·60 cm.

(1) In about 50 per cent. of specimens there is a more or less well-marked angle, marking the separation of the trochlea from the internal articular surface. This is quite independent of the internal semilunar depression, from which it is separated by a smooth rounded ridge.

In the remaining 50 per cent. the edge presents an uninterrupted convexity.

(2) *The Depression for the Internal Lateral Ligament.*—This is more distinct in a fresh specimen. It is not very well marked in the majority of specimens, and is a shallow broad depression; when absent, its position is shown by the corresponding surface being covered with cartilage to a greater extent than elsewhere.

The External Articular Surface.—On this surface are found depressions for the following structures:—

(1) The anterior crucial ligament.
(2) The external semilunar cartilage.
(3) The external tibial spine.
(4) Posterior depression for external semilunar cartilage.

On its peripheral border there is a notch for the corresponding semilunar cartilage, a groove for the external lateral ligament, and one for the tendon of the popliteus.

Anterior Crucial Depression.—At the junction of the external and intero-internal borders of the non-articular surface is found in about 30 per cent. of cases a conspicuous groove, having an average width of ·77 cm. (varies between ·50 and 1·00 cm.); it is best marked near the non-articular surface. Anteriorly it widens out, and is finally lost on the central concavity of the trochlea.

The External Semilunar Depression.—There is usually a well-marked deep notch limiting the external articular surface anteriorly. It is best marked externally where it encroaches upon the periphery of the articular surface. Internally it becomes gradually lost on an elevation which separates it from the depression for the external spine. Its average length and breadth are 1·50 × 1·00 respectively. In complete extension of the joint, this depression is placed immediately over the junction of the internal and external borders of the external articular surface of the tibia.

External Spinal Depression.—Immediately external to the anterior third of the external border of the non-articular surface is a distinct smooth, shallow depression (1·50 × ·60), directed obliquely outwards and forwards. It is separated from the semilunar depression by a smooth elevation, well marked in 75 per cent.

In two or three specimens there is connected to the hinder and inner extremity of the former depression a shorter one running antero-posteriorly.

The Posterior Semilunar Depression.—The external articular surface terminates in more than 60 per cent. by an elevation which is commonly the posterior boundary of a distinct transverse groove, which lodges the semilunar cartilage in extreme flexion.

The External Articular Periphery.—This presents three points of interest:—

(1) Depression for the external semilunar cartilage.—In 65 per cent. of cases, this is a conspicuous notch, about 1·10 cm. in width, with rounded edges, marking the separation of the trochlea from the external articular surface.

(2) *External Lateral Depression.*—This is a smooth, usually conspicuous groove, about ·60 cm. in width. It is about 2·50

cm. distant from (1). In most specimens in extension of the joint, the tendon of the popliteus is included between the external lateral ligament and the bone.

(3) *Groove for the Tendon of the Popliteus.*—A conspicuous deep groove (1·75 × 1·00 cm.) runs upwards and backwards to within ·75 cm. of the posterior end of the articular periphery. It is so disposed as to be horizontal in the semiflexed position of the joint. It is separated from (2) by an interval of about 1·50 cm.

The non-articular surface is bounded by—(1) The internal border. (2) The antero-internal border. (3) The external border.

(1) *The Internal Border* is almost invariably smooth and rounded at its junction with the antero-internal border. The remaining anterior half of the border may present either a marked concavity, or it may be straight or even slightly convex. The rest of the border presents a roughened conspicuous rim, excavated on its superior aspect.

(2) *The Antero-Internal Border* is usually smooth and concave where it joins the internal border, being grooved by the internal spine and by the anterior crucial ligament where it joins the external border. The intervening portion may or may not be ridged. It is usually markedly or slightly concave, but may be straight or even convex when the impressions at its junction with the adjacent borders are not well marked.

It, as well as the distance between the two condyles, varies considerably in length.

(3) *The External Border* is usually sharp and directed antero-posteriorly; it presents a concavity at the commencement of the vertical part.

The intra-articular non-articular area has three surfaces:—

(1) *Internal Surface* presents a conspicuous depression, deepest at its centre, which is usually confined to the posterior ⅔rds of the surface, but there may be a depression forming a continuous groove with the antero-internal surface.

The anterior ⅓rd is usually directed upwards and slightly backwards, and is on the same plane as the border.

(2) *The Antero-Internal Surface* is usually flush with the border. It is continuous with the internal surface by a smooth concavity,

and is joined at rather more than a right angle by the external surface. It may be excavated immediately above the border, the rest of the surface being plane, or it may be nearly uniformly concave.

(3) *External Surface.*—This surface is directed forwards and outwards, and is usually almost plane, though it does not usually present such a smooth appearance as the other surfaces. It is frequently excavated just above the border, or it may be uniformly concave.

Posteriorly there is a well-marked smooth ridge which separates the intra-articular non-articular surface from the rest of the shaft.

MEASUREMENTS.	Greatest Length.	Least Length.	Average Length.
	cm.	cm.	cm.
Length of the bone, ...	51·60	38·70	45·30
Diameter of the lower extremity, ...	9·20	6·90	8·00
Separation of the articular surfaces at their posterior extremities, ...	2·90	1·50	2·30
Separation of the articular surfaces at level of junction of internal and antero-internal borders, . .	2·90	1·20	1·80
Width of trochlea (superiorly), ...	4·65	3·00	3·90
Length of trochlea measured from its highest point internally to the centre of the coronal portion of the internal semilunar depression, . . .	3·00	2·10	2·60
Length of trochlea measured from its highest point externally to the centre of the depression for external semilunar, ...	5·00	3·00	4·00
Length of trochlea measured from its highest point externally to the centre of the depression for external tibial spine, ...	3·25	2·00	2·50
Length of trochlea measured from its highest point externally to the centre of the depression for internal semilunar, ...	5·50	3·20	4·50
Transverse diameter of the internal condyle, . .	4·00	2·50	3·30
Transverse diameter of the external condyle, . .	3·90	2·70	3·40
Greatest width of the internal articular surface, .	3·40	2·00	2·50
Greatest width of the external articular surface, .	3·30	2·10	2·80

Comparison of the Articular Surfaces (see Plate X. figs. *a*, *b*, *c*, *d*).

Internal articular surface. **External articular surface.**

Surface Measurements.		
	Internal.	External.
Highest, . .	8·60	8·40
Lowest, . .	6·60	5·30
Average, . .	7·70	6·70

The above are the averages of curves taken from the centre of the semilunar depressions on either side. (Plate X. figs. *c*, *d*.)

The following are the measurements of the anterior horizontal portions of the articular surfaces.

	Highest.	Lowest.	Average.
Internal articular surface, . .	5·50	3·50	4·50
External articular surface, . .	3·50	2·50	3·00

The average difference between the measurements of 40 specimens is 1·30. The following are measurements from a point 3·00 cm. from the posterior limit of the articular surfaces:—

	Highest.	Lowest.	Average.
Internal articular surface, . .	5·70	4·30	4·40
External articular surface, . .	4·50	2·30	3·30

In these specimens the average difference is 1·20.

For transverse curve of horizontal part of articular surfaces see Plate X. figs. 1–4.

From the above it is seen that the two condyles closely resemble each other in the length of their antero-posterior and transverse axes, the surface measurement of their curves, and their average conformation.

The horizontal parts of the articular surfaces diverge from the central depressed part of the trochlea, until they are about 2·00 cm. apart, as the external usually runs almost directly backwards, the internal condyle is directed inwards and backwards.

Both the horizontal parts are at a lower level peripherally than they are mesially; the internal is uniformly convex from before backwards and from side to side, whereas the external is obviously more flattened, especially anteriorly and internally, and is about 0·5 cm. broader. The similarity in the average curves and lengths of the articular surfaces is accounted for by the greater length of the outer side of the trochlea, and a corresponding deficiency in the length of the horizontal part of the external articular surface, in each case amounting to about 1·50 cm.

Another feature of these surfaces is the difference between the impressions made by the spines of the tibial articular surface. The depression for the internal spine is rather more than 2·00 cm. in length and is directed antero-posteriorly (with respect to the articular surface), while that for the external is directed outwards and forwards, and is usually rather less than 1·50 cm. long.

In comparing the vertical parts, they are both directed somewhat inwards, the external more conspicuously so than the internal. The external is more convex, broader, and more elevated peripherally than the internal, at its junction with the horizontal part. Posteriorly, the articular surface extends farther back on the inner side, and is grooved for the cartilage; on the outer side, the condyle ends abruptly in an elevation, which has a shallow depression in front of it for the reception of the external semilunar cartilage in extreme flexion.

The impressions on the articular surface of the femur can be divided into three classes:—

(1) Those produced when the joint is fixed in the extended position.

(2) Those produced when the joint is undergoing the movements of flexion and extension.

(3) Those produced when joint is fixed in the flexed position.

(1) When the knee-joint is fully extended, the semilunar cartilages are tightly wedged between the semilunar depressions and the tibia; the tense anterior crucial ligament supports the median portion of the femur; the internal and external lateral ligaments making impressions vertically below their attachments.

(2) During movements of the joints, impressions are produced by the internal and external spines of the tibia: the former is a groove about 1·60 c.m. in length, skirting the greater part of the long horizontal part of the articular surface, and running from before backwards; the latter shorter, broader, and more shallow, running from within forwards and outwards.

EXPLANATION OF PLATE X.

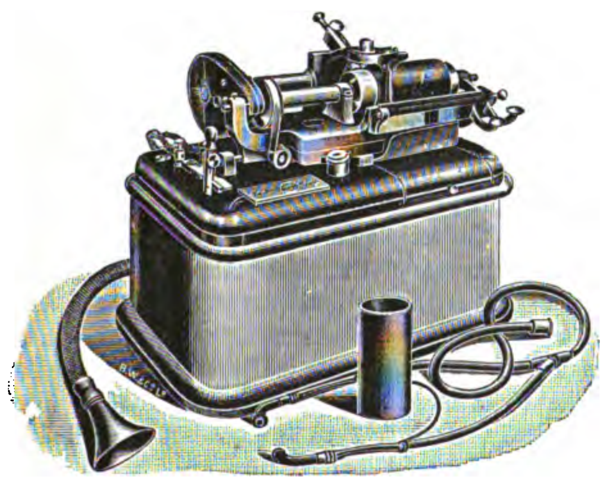
Figs. *a*, *b*, *c*, *d*. Comparison of the articular surfaces. These curves were obtained by means of lead foil, and were taken from one extremity of the articular surface to the other, including the trochlea. The numbers are the average of the forty specimens.

Figs. 1, 2, 3, 4 show the transverse curve of the horizontal part of the articular surfaces immediately behind the semilunar depression. Those to the observer's left are the internal surface, those to his right are the external surface.

(*To be continued.*)

ON THE TONE AND CURVES OF THE PHONOGRAPH. By JOHN G. M'KENDRICK, M.D., LL.D., F.R.S., *Professor of Physiology in the University of Glasgow.* (PLATES XI., XII., XIII.)

1. DURING the last twelve months my attention has been largely occupied with the phonograph. The instrument chiefly studied has been the machine used in this country,[1] which is so geared that the wax cylinder, $6\frac{7}{8}$ inches in circumference, makes two revolutions in one second, while the spiral grooves described on the cylinder are only $\frac{1}{200}$ inch apart. A spiral line about 136 yards in length may be described on the cylinder, and the recording or reproducing point travels over this distance in about 6 minutes. The instrument is shown in the accompanying figure.[2]



2. By using conical resonators of considerable size, made of thin block tin, the tone of the phonograph can be much increased in volume, and the sounds become quite audible and agreeable

[1] Supplied by the Edison-Bell Phonograph Corporation, who have kindly given me much assistance in this investigation.

[2] As to the mechanism and uses of the phonograph, see *A Practical Guide to the Use of the Phonograph.* By James L. Andem, Cincinnati, Ohio, 1892.

in a large room. The method of conveying the sounds directly to the ears by flexible tubes may be discarded when it is desirable to allow many persons to hear the same tones. The largest resonator I use is about 9 feet in length, with a diameter at the widest end of 3½ feet.[1] The best results yet obtained have been with the use of tin resonators. A conical resonator about 3 feet in length and 6 inches in diameter at its wide end, made of thin aluminium, gives remarkably good tones, and encourages me to have another made of larger size.[2] Wood, vulcanite, papier-maché, all have the effect of muffling the tones. By placing a Y-shaped tube over the disk of the phonograph and connecting each limb of the Y with a separate resonator, a wonderful augmentation of volume of tone may be obtained. Large resonators have also the effect of quenching many of the higher partials produced by the vibrations of the glass disk of the phonograph, and thus the quality of tone is softened and improved. This is well illustrated by placing the aluminium resonator in connection with the phonograph so that its wide end is opposite to the wide end of a large tin resonator. The tone then becomes louder and of better quality.

3. I have endeavoured to increase volume of tone by connecting with the phonograph (*a*) Mr Alfred Graham's transmitter along with (*b*) the loud speaking telephone also made by Mr Graham.[3] By placing a large resonator in front of *b*, and by using a glass plate in the telephone (having the keeper of the magnet attached to the centre of the glass plate), the volume of tone is greater than that obtained by the large resonator alone, but the quality undoubtedly suffers. A certain hollowness of tone is communicated by the arrangement, and the telephone speaks better for certain tones than for others. I always place in circuit a dry cell battery of from 7 to 9 volts. A very fine effect is obtained by using the Y-shaped tube already referred to, connecting one limb with a large resonator and the other with the telephonic arrangement. In this case the resonator gives

[1] The use of resonators of considerable size has been practised by Mr Edison, and is especially common in America, but I am not aware that anyone has used resonators of so great a size as above indicated.

[2] The aluminium resonator was obtained for me by my friend Mr Paul Rottenburg, merchant, Glasgow.

[3] Supplied to me by Messrs Muirhead & Co., electrical engineers, Westminster.

precision and definiteness to the sound, say, of a military band, while the telephonic arrangement increases the volume of tone. It is easy to fit up several telephonic arrangements, all linked together; and by placing these in different parts of the room, the effect becomes next to marvellous.

4. Apart from the pleasure of working with the instrument, one cannot help having a special interest in the question of the forms of the curves described on the wax cylinder. Many attempts have been made to obtain tracings of the vibrations of membranes and of glass or metallic disks. In 1856 Léon Scott invented the well-known phonautograph, which may be regarded as the precursor of the phonograph, and by which vibrations were recorded. Donders applied this instrument to the investigation of vowel sounds. Next came the logograph of W. H. Barlow, by which curves were obtained by the vibrations of a thin membrane of gold-beater's skin. About 1873 Koenig introduced his manometric flames, and flame-pictures of vibrations were thus obtained. In 1876 Stein succeeded in photographing the vibrations of strings.[1] All these instruments made it possible to record vibrations, but the sound could not be reproduced from the tracings thus obtained. This was accomplished by Edison, whose first phonograph was patented in January 1877. In 1878 Fleeming Jenkin and J. A. Ewing[2] succeeded in obtaining tracings of the record of vowel sounds on the tin-foil phonograph, and the curves were submitted to harmonic analysis.

Tracings were taken, or at all events the marks on the tin-foil were examined, by Grützner, Mayer, Graham-Bell, Preece, and Lahr.[3] The imperfections of the tin-foil phonograph made progress impossible for a good many years (from 1877 till 1888), during which time, however, the ingenuity of Edison was engaged in working out the mechanical details of the wax-cylinder phonograph as we now have it, one of the most beautiful and (almost) perfect of instruments. The subject was then taken up by L.

[1] *Die Photographie der Tone.* Von Dr Med. S. Th. Stein Poggendorff's Annalen., 1876, p. 142.

[2] *Trans. Roy. Soc. Edin.*, "On the Harmonic Analysis of certain Vowe Sounds," vol. xxviii. p. 745.

[3] *The Telephone, The Microphone, and the Phonograph.* By Count du Moncel, London, 1884. Also *The Speaking Telephone and Talking Phonograph.* By George B. Prescott, New York, 1878.

Hermann of Königsberg, and he succeeded in obtaining photographs of the vibrations produced by the vowel sounds, a beam of light reflected from a small mirror attached to the vibrating disk of the phonograph being allowed to fall on a sensitive photograph film while the phonograph was slowly travelling.[1] The curves thus obtained were very beautiful, and present a striking resemblance to some of Koenig's flame-pictures. Finally, Boeke of Alkmaar,[2] in a laborious microscopical research, measured the transverse diameters of the depressions on the wax cylinder at different depths, and from these measurements calculated the depths of the curves. He thus, in a manner, reconstructed the marks on a large scale. These are all the attempts to reproduce the curves that have come under my notice. It has always been a matter of surprise to me that the question has not been further investigated by physicists. The recording and analysis of these curves are somewhat out of the beat of a physiologist, although their investigation is of much interest when we view it as bearing on the theory of vowel tones, the appreciation of quality of tone, and the mode of action of the membrana tympani and chain of ossicles.

5. I have endeavoured to study the marks on the wax cylinder in three different ways:—(*a*) taking a cast of the surface of the cylinder; (*b*) taking a microphotograph of a portion of the surface of the cylinder; and (*c*) recording the curves on a slowly moving surface, by a method to be afterwards described. (*a*) As regards the first method, taking casts, which was also attempted by Hermann, the results were not very satisfactory. The most efficient method followed by me was to paint on the cylinder, with a camel-hair brush, a layer of celloidin dissolved in ether. This soon hardened, and it could then be peeled off. The thin film thus obtained was then inverted on the stage of a microscope, and the marks were seen in relief. Microphotographs were also taken of the films. (See Plate XI. fig. 10.) This method had the disadvantage of flattening the elevations in the curves, but beautiful pictures of the depressions were obtained.

[1] *Ueber das Verhalten der Vocale am neuen Edisonschen Phonographen.* Pflüger's Archiv., vol. 47, 1890, p. 42; also *Phonophotographische Untersuchungen*, ii. p. 44; also *Phonophotographische Untersuchungen*, iii. p. 347.

[2] *Mikroskopische Phonogrammstudien.* Pflüger's Archiv., vol. 50, 1891, p. 297.

(*b*) I took numerous photographs, with the aid of microscope and camera, of portions of surface of the cylinder on which were records made by many instruments and by the voice. Specimens of such photographs are shown in Plate XI. Each figure represents $\frac{1}{5}$th of an inch on the surface of the wax cylinder, magnified about 14 diameters. The vertical grooves seen in each figure are $\frac{1}{200}$th inch apart, and the length of each figure represents in time $\frac{1}{64}$th second, that is to say, when each tracing was recorded, the sapphire point of the marker connected with the vibrating plate of the phonograph travelled over the distance represented in magnified proportions in $\frac{1}{64}$th part of a second. (Fig. 8 is slightly shorter.) By counting the number of indentations or marks, which in a photograph have a curious appearance of being in relief, one can at once determine approximately the pitch of the tone, the vibrations of which made the impressions. Tracing 6 represents the picture of tones produced by the violin, and it will be seen that they vary much in character. Sometimes the marks are a little apart from each other, and at other times they blend into each other, the mark widening out as the sapphire point cut into the wax and then contracting as it receded. It is to be borne in mind that even when the glass disk of the phonograph is not vibrating, the sapphire-pointed marker connected with it is ploughing a groove in the cylinder; and when the glass disk vibrates, each vibration cuts deeper into the groove. The moniliform marking (seen also in 5, the tones of a tenor voice, and in 7, the tones of a flute) shows that the disk may not in some instances return to its position of rest for a short time. In other cases, the sapphire point cuts into the bottom of the groove as the glass disk is suddenly pressed in, and then the disk flies back suddenly to its position of rest. It is interesting to find that during many individual vibrations there may be a plus pressure on the outer surface of the glass disk, and that each individual vibration adds to and takes from this pressure.

The first four examples (Plate XI., 1, 2, 3, and 4) are given to show the accuracy of the phonograph. I took four records from four of Koenig's tuning-forks, the vibration numbers of which were 64, 128, 256, 512. When the record was taken the cylinder of the phonograph was making as nearly as possible two revolutions

per second, the rate at which all records should be taken. Photographs were then taken of portions of the cylinder representing $\frac{1}{64}$th of a second; these are shown in figs. 1, 2, 3, 4, in Plate XI. It will be noticed that in 1 (64) there is one lozenge-shaped mark, in 2 (128) there are two, in 3 (256) there are four, and in 4 (512) there are eight marks.

Interesting, however, as this method of investigation is, it does not give the form of the curves represented by the bottoms of the depressions made by each vibration of the disk of the phonograph, and it was abandoned for the next method of mechanically tracing these curves.

6. A mechanical representation of the curves presents many difficulties. These were so far overcome by the device of Jenkin and Ewing with the tin-foil phonograph. The method followed by these observers, which was entirely mechanical, was to cause the disk of the phonograph to record its movements. As already mentioned, Hermann photographed the oscillations of a beam of light reflected from a small mirror connected with the disk of the phonograph, the whole apparatus moving slowly. My notion was to adapt a light lever to a marker connected with the phonograph itself, and so to arrange that it (the point of the marker) would travel over all the ups and downs of the phonographic curve on the wax cylinder at an extremely slow rate. The obvious objection to this method is that the inertia of the lever might cause extraneous vibrations, while at the same time the smaller marks on the wax cylinder might be missed, an objection, however, that may be removed by (*a*) reducing friction to a minimum, and (*b*) moving the phonograph cylinder so slowly as to make the movement almost invisible to the naked eye.

After various attempts with simple appliances, the apparatus shown in Plate XII. was fitted up, and by means of it the taking of curves became comparatively easy. In fig. 1, Plate XII., a diagram of the arrangement is shown as simply as possible.[1] The apparatus was not specially made for the experiment, but consisted of fittings in my own laboratory. It might be simplified still further, and made even more convenient. The

[1] For this drawing I am indebted to Mr Mackinnon, assistant to the Professor of Engineering.

motive power for driving the apparatus is a small water motor acting on a wooden wheel. From this wheel two trains of wheels or pulleys pass, the one set, namely, 2, 3, 4, and 5′, being gradually geared down so as to drive the cylinder of the phonograph, 6,[1] at an extremely slow rate, and the other set, namely, 2′, 3′, and 4′, to drive at a slow rate the recording drum *a*. By this arrangement the rate of rotation of the cylinder of the phonograph is about once in five or six *minutes*, instead of being once in one-half second, the usual speed in recording. The drum, *a*, also moves very slowly, but a little faster (not twice as fast) than the cylinder of the phonograph, the object being to open out the curves somewhat in a linear direction. By attaching an electric arrangement to the axle of the mandril carrying the phonograph cylinder, 6, the time of each revolution of the phonograph cylinder was registered on the drum *a*. Thus the amount of surface on *a*, representing one-half second on cylinder 6, could always be measured. As a rule, it was found that 3 inches of the drum *a* represented one-tenth of a second. Occasionally it was one-seventh of a second, but it could be so timed as to represent one-tenth.

In the next place, a light lever of hard wood, braced like the mast of a ship, was fixed firmly into a socket bored into the lead weight, *i k*, seen in fig. 2, Plate XII. This square leaden weight is hinged to the frame carrying the recording and reproducing part of the phonograph by the hinge, *h*, a slot is cut in the under surface of the lead weight, as seen in fig. 3, Pl. XII, and the marker, *a n* (also *m n* in fig. 2), moves on an axle delicately pivoted to the sides of the slot. In fig. 2, at the end of *m*, is seen the wire, *w*, passing up to the glass disk, *d*, of the phonograph. It will be seen that the point of *m n* touches the surface of the wax cylinder, *o*, *o*, *o*, *o*. The lead weight accurately follows the movements of *m n*, the marker, and the lever, *s*, records these movements, as seen in fig. 1, on the drum, *a*. The slowness of movement does away with any movement of *s*, except that which is communicated to it from the lead weight and from the marker, *m n*, and to prevent all extraneous vibra-

[1] The cord passes over (*b*), the wheel seen on the left end of the phonograph spindle in the figure showing the instrument. The wheel will be recognised by a tape band passing vertically over it.

tions, the phonograph was seated on a solid stone pillar erected for a galvanometer. The point of the lever *s* is the point of a very fine hard needle, and *a* was covered with very smooth paper, carefully smoked. As the marker of the phonograph is always travelling to the one side so as to describe a spiral groove, that is, towards the observer, when one looks at fig. 1, it is evident that the point of the lever *x* would soon leave the surface of *a*. To get rid of this difficulty, the drum *a* is mounted on a kind of movable table moving in slots, and controlled by the fine screw *c* (one thousand to the inch thread). And thus it was easy, by a turn of *c*, to keep the point of *x* in contact with the surface of *a*. Finally, the movable table rested on a plate of metal moving vertically in slots by turning the fine screw *b*, and thus, after a tracing had been taken once round *a*, it was easy to move *a* a little up or down without disturbing the lever *x* (fig. 1). Thus I had three motions of *a*, vertical, rotatory, and horizontal, and there were two movements of the cylinder of the phonograph *b*, rotatory and horizontal. Everything was as steady as it could be made, and the apparatus worked almost automatically, the point *n* (fig. 2) slowly *crawling* over the surface of the wax cylinder *o*, about 600 times slower than when the record was made on the wax cylinder.

After tracings had been taken, the paper on *a* was varnished and it was cut into longitudinal strips, each three inches in length, and the strips were mounted between two ordinary microscope slides (English make) in the way that slides are prepared for the lantern. Such slips can then be examined by the microscope and the curves may be drawn by Abbe's camera lucida, or any portion of the tracing may be photographed by a convenient microphotographic apparatus. Thus the size of the curves may be much increased, and so made available for purposes of harmonic analysis. (See Plate XIII. and description of plate.)

In the present paper, I desire only to describe the method and to show portions of a few curves (to be examined with the aid of the description of the Plate), leaving such a discussion of these as may be necessary to a communication to be made at a future time. Meanwhile, I would point out how similar these curves are to those obtained long ago with the phonauto-

graph. It is interesting, also, to compare them with the curves shown by Professor Hermann in the papers already quoted. The curves obtained by Hermann's method are more pointed at the apex, closer together, and have generally a greater resemblance to Koenig's flame-pictures than those obtained by me.[1] I have endeavoured to state the time relations of the curves. By counting the number of waves in a given linear distance, an approximation is at once got to the pitch of the tone under consideration. It will also be noticed that the pitch, as one would expect, in a complicated succession of sounds, quickly alters, and it appears to me that the method now illustrated may enable us to answer the question as to the *number* of vibrations required to appreciate the pitch of any given tone. The varying forms of the curves is also striking, pendular in character for the piccolo, less so for the flute, more complicated in the bassoon, still more so in the cornet, and most of all in the record of a military band. The analysis of these curves will test the soundness of the theoretical views now held as to the kind of movements made by vibrating disks, such as the drum of the ear. The whole matter is thus of great interest both to physiologists and to physicists. Possibly, also, the subject may have a practical outcome.[2] Could we only obtain accurately the curves of syllables, by putting these together in a conceivable machine, we might "set up" speech curves instead of type, and have a machine which, without having been spoken to, would appeal to the ears by sound and speech.

[1] See *Pflüger's Archiv.*, 1890. Tafel viii. p. 390.

[2] Dr John Macintyre of Glasgow has put the phonograph to extensive use in his practice as a laryngologist, and he has shown that the instrument may be adapted to medical purposes.

DESCRIPTION OF PLATES XI., XII., XIII.

Plate XI.

(In Figs. 1, 2, 3, 4, 5, 6, 7, and 9, the vertical length of the tracing represents 1/64 sec., and the cylinder is rotating as from the bottom to the top of each tracing.)

Fig. 1. Record of tuning-fork, 64 vibs. per sec. (one long mark).
Fig. 2. Record of tuning-fork, 128 vibs. per sec. (two marks).
Fig. 3. Record of tuning-fork, 256 vibs. per sec. (four marks)

Fig. 4. Record of tuning-fork, 512 vibs. per sec. (eight marks).

Fig. 5. Powerful tenor voice, about 640 vibs. per sec.

Fig. 6. Violin—Scotch reel "Tullochgorum," about 640 vibs. per sec.

Fig. 7. Flute—portion of "Il Trovatore," about 1000 vibs. per sec. near do_5.

Fig. 8. Vowel O, sung by human voice. An imperfect photograph.

Fig. 9. Full organ—taken 40 feet from organ—portion of Mendelsohn's "Wedding March." Remarkable for full, powerful chords. Piano record is similar.

Fig. 10. Portion of celloidin cast of cylinder on which was recorded a march by a military band. Note the varying forms of the marks.

Plate XII.

Fig. 1. Shows diagram of recording apparatus described in the text.

Fig. 2. Shows on a larger scale than in Fig. 1 the recording arrangement. *See* text.

Fig. 3. Under-surface of leaden weight to which recording lever was attached.

Plate XIII.

Fig. 1. Facsimile of curves obtained from record of old English coach horn.

Fig. 2. Facsimile of curves obtained from record of a military band.

Note 1.—These curves (3 inches of the tracing representing one-tenth sec.,—that is to say, the curves in 3 inches were recorded on the cylinder of the phonograph in one-tenth sec.) should be examined with a magnifying glass. In the two upper lines of 1, note the uniform character of the curves. In the third line the character of the curve alters. These are tracings of the marks produced by the long-drawn, clear, piercing tones of the horn. In 2 the upper and lower lines show great variety of curve form. The middle line shows no curves.

Note 2.—Figs. 3 to 12 are from microphotographs of curves similar (though varying in amplitude) to those in 1 and 2, but magnified from 5 to 10 diameters. Only short portions of the curves are given, to illustrate the great variety in form.

Fig. 3. Vibrations of large tuning-fork, 32 vibs. per sec.

Fig. 4. Cornet.

Fig. 5. Bassoon (two curves).

Fig. 6. Cornet.

Fig. 7. Flute.

Fig. 8. Old English coach horn (two curves). Portions of 1.

Fig. 9. Military band. Three curves, varying much in shape.

Fig. 10. Piccolo. Three curves. The upper is the best.

ON THE FORM OF THE STERNUM IN THE GREENLAND RIGHT-WHALE (*Balæna mysticetus*). By JOHN STRUTHERS, M.D., LL.D. (PLATE XIV.)

As the two sterna described in this memoir were found on the shores of Cumberland Sound, Davis Straits, there need be no doubt as to the species of Right-whale to which they belong. The figures of the bone given by authors in the course of their description of the skeleton show great and perplexing differences of form, and, so far as I am aware, no endeavour has been made to account for these differences or to explain the meaning of the shape, curvatures, and other characters of this great bone. That cannot be done without comparison of specimens and the opportunity of doing so is rare. These two specimens look very different at first sight, but a close study of them shows the meaning of the shape and other characters of the bone, and how there may be variation consistent with its adaptations.

Order, and Parts noticed.

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The sternum of the Right-whale is known to consist of one expanded plate, with which the first pair of ribs are articulated, the second and other ribs being a-sternal in this and in all other whale-bone whales.

Ossification and Form of the Sternum as given by authors.

Ossification.—Eschricht and Reinhardt[1] give a figure and description of the sternum of a female fœtus of this species.

[1] *On the Greenland Right-Whale*, Ray Society's Translation, edited by Sir William Flower, 1866, p. 118.

The fœtus being fully 8½ feet long, may be taken as ⅔ grown, as a new-born fœtus mentioned by them was fully 13 feet long. The vertebral rib was "completely calcified" to within ½ inch of its sternal end; the interposed plate which they found representing the sternal rib was cartilaginous; and the sternum consisted of one entirely cartilaginous plate. They found no trace of a cartilage representing a second sternal element behind this plate. They remark:—

"For those pairs of ribs immediately succeeding the first approach pretty nearly to the mesial line of the ventral surface, and in this line we only found a slight fibrous tissue corresponding to the so-called *linea alba*, but this fibrous tissue did neither contain any trace of cartilage nor was it in any close connection with the periosteal membrane of the ribs, or that of the sternum."[1]

Referring to a commonly received distinction between the toothed cetacea and the whale-bone whales in regard to the ossification of the sternum, Van Beneden and Gervais, in their great work on the cetacea,[2] remark:—

"Dans les mysticètes il n'a qu'un seul point d'ossification, et dans les cétodontes on lui en reconnait toujours plusieurs et ils occupent les deux moitiés longitudinales de cet os."

If that is so, the reason for the difference is not evident. Mesial and bi-lateral ossification of the sternum occur variously among mammals. In the larger experience anatomy has of the human sternum, bi-lateral ossification occurs as a not infrequent variation. The generalisation quoted above may perhaps require to be modified in regard to both groups of the cetacea on further critical examination. Nor is it evident why in the economy of the whalebone whales they in particular should have only the first pair of ribs connected to the sternum. To say that it is because the meso-sternum is absent, appears to be reversing cause and effect.

Form.—In the figure of the sternum of the *fœtal* Mysticetus

[1] Absence of all but the first segment of the sternum had been assumed to be the case in all whale-bone whales, but in the 19½-feet-long male fœtus of a great fin-whale (*Balænoptera Sibbaldii*, about 78 feet long) Sir William Turner found a small second almond-shaped cartilage behind the great three-lobed cartilage, and gives a figure of the parts ("On the Sternum and Ossa Innominata of the Longniddry Whale"—*This Journal*, 1870). The preparation is preserved in the Anatomical Museum of the University of Edinburgh. This very interesting observation should lead those who may have the opportunity of dissecting the fœtus of any whale-bone whale to look carefully into this point.

[2] *Ostéographie des Cétacés, vivants et fossiles*, 1880, p. 22.

given by Eschricht and Reinhardt, already referred to, the form is narrower than in the adults. The length is to the greatest breadth as about 5 to 3. The greatest breadth is at the unequal lateral angles in front of the costal notch; the anterior border rises into a well-marked blunt mesial peak; the costal notch is at about the middle on the right side, more anterior on the left side; the posterior fourth tapers rapidly to a narrow point.

In the figure given by the same authors (Plate II. fig. 3) from their *half-grown* (22½-feet-long) female skeleton of Mysticetus, the sternum is semicircularly convex at the anterior end, with indication of progressing ossification; tapers gradually to a blunt point behind; the costal connection rather behind the middle; and in its general form the sternum is broader in proportion to its length than in the usual adult condition. In the figure, the length is to the breadth as 5 to 4. Figures of the relation of the sternum to the ribs from articulated skeletons of whale-bone whales in museums are not always to be relied on as giving the natural relation, but this figure is valuable as showing the natural relation, the parts "all still remaining in their natural connection." The end of the rib rests in the sternal facet on both sides. The ribs are broader some way external to their sternal end than at the end.

In the figure of the sternum of Mysticetus given by Van Beneden and Gervais (*loc. cit.*, Pl. IV. and V., fig. 24) apparently from the adult female skeleton in the Brussels museum, the form is that of a blunt ovoid, a notch at the middle of the anterior border, however, giving somewhat the heart-shape. In the figure, the length is to the breadth as 5 to 4½. The middle of the well-defined costal notch is a little in front of the middle of the bone. Nearly the whole of the end of the rib is represented as in relation with the costal notch on the left side. On the right side, the end of the rib, broader than the left, extends some way beyond the notch both in front and behind, bevelled at both angles.[1]

[1] It may here be noted, in contrast, that in the figure given in the same work of the sternum of *Balæna Australis* (Pl. I. and II. fig. 6), Cape of Good Hope, from the skeleton in the Paris museum, the form is very different. The whole of the cervical border is markedly concave, the posterior end blunt; the length is to the breadth as about 5 to 4; yet the figure suggests rather an elongated form, owing to the narrowness of the posterior ⅓. The end of the rib is proportionately broad, about ⅖ of the length of the sternum, but lines added indicate

Eschricht and Reinhardt (*loc. cit.*, p. 119) remark:—"As to the shape of the sternum in the Greenland whale, we must on the whole refer our readers to our illustrations of those of the fœtus and the half-grown individual. In our larger skeletons, however, the sternum had not exactly the same form, and some other examples which we have had for our examination have again proved different. They all agree in the following points. The external surface, which looks forwards and downwards, is flat in the longitudinal direction, but convex transversely, the internal surface looking backwards and upwards is convex longitudinally and concave transversely; the sternum has its greatest breadth anteriorly, especially before the attachment of the ribs; behind it runs out into an obtuse point. The lateral margins are in the middle, or a little in front of this, very much thickened, by which the attachment of the ribs is indicated; and posteriorly they become gradually thinner. But the anterior margin is sometimes somewhat convex, as in our 22-feet-long skeleton (Pl. II. fig. 3); sometimes, on the contrary, having a greater or smaller notch in the middle. The length of the sternum is always greater than its breadth; in that of our 44½-feet-long skeleton the former is 20 inches, the latter 19 inches; in another one the left is 24, the breadth 19 inches; in a third the length is 23, the breadth 16½ inches."

In his *Appendix* to the Memoir of Eschricht and Reinhardt, Sir William Flower says, of the sternum of the adult female Greenland Right-whale in the museum of the London College of Surgeons:—

"The sternum is heart-shaped, but with the anterior border very slightly excavated, and the posterior end much narrowed. It is 22 inches in length and 20 in breadth."

In the figure given by him,[1] presumably from that skeleton, the general form is heart-shaped; angles broad, rounded and not quite symmetrical; anterior border concave; sides flattened and sinuous, slanting to a moderately blunt end; indication of

articulation only to the anterior ¼ of the sternum. In the figure they give from the *young* skeleton of *Balæna Australis* (fig. 18 of same Plate), the costal connection is figured as on the anterior ¼ of the sternum; the cervical border is gently convex; length to breadth is as 5 to a little over 3. The general figure suggests the form of a blunt-angled triangle, with slightly convex sides; figure 6, the same with concave sides.

In the figure they give of the sternum of *Balæna Antipodarum* (Pl. III. fig. 2), only the anterior angle of the broadly excavated sternal end of the rib is represented as articulating with the sternum. The place of articulation is the angle of the sternum, quite at the fore part of the side; and the costal notch there is distinctly indicated. The breadth of the end of the rib is equal to the entire length of the side of the sternum, and, except at its anterior angle, is represented as widely separated from the sternum. The sternum is short, a little concave on the cervical border, blunt at the posterior end. The breadth is equal to the length; the greatest breadth is at the posterior end of the costal notch.

[1] *Osteology of the Mammalia*, 3rd Ed., 1885, p. 99.

costal facets places the middle of them rather in front of the middle of the bone; greatest breadth just in front of costal facets; proportion of length to breadth is as 5 to 4½.

Comparison with the form of the sternum in Fin-whales.—I refer more particularly to the figure given of these parts in my 64-feet-long *Balænoptera musculus* (in *this Journal*, 1871, p. 107, fig. 4), in which the natural relation of the sternum to the first rib is shown. There it is seen that the sternum has the form of a cross, the wings broader than the median body of the cross. The 12-inch-broad end of the rib articulates with the sternum only by about its anterior ¼, the posterior ¾ of the end of the rib being widely separated from the beak of the sternum, and projecting backwards beyond the beak. The rib articulates with the sternum at two places; internally, by its anterior ¼, at the recess between the median beam and the wing of the sternum; and, 6 inches further out, by a like articulation with the outer part of the wing; both connections being by fibrous tissue.

The two anterior bays of the cross may, in some specimens of B. musculus be more or less filled up by bony expansion, as seen in the figure given by Sir W. Flower (*Osteology of the Mammalia*, p. 100, fig. 39), and still more in one in my possession, leaving more or less of a mesial fissure or foramen. The difference in the sternum of the Right-whale is that all the four bays of the cross are filled up, forming a great ovoid plate of bone, and that the end of the rib rests lengthily against the side of the plate, the two articulations of the Finner being thus thrown into one continuous articulation. It remains a question whether this form of sternum in Mysticetus is in adaptation to the support of the rib, or whether this mode of articulation is the result of the form of the sternum required for other adaptations.

In the thicknesses of this great ovoid plate we can recognise the fundamental form of the two beams of the cross, a longitudinal median beam, prolonged backwards, and a transverse beam placed between the ends of the first pair of ribs. The two anterior bays of the cross are filled up broadly, giving the broad anterior end of the ovoid; the two posterior bays less broadly and tapering towards the prolonged median beam, giving the narrow end of the ovoid. These considerations enable us to understand the form and to see the meaning of the various thicknesses and curvatures of this great bone.

Division into Regions.—I would accordingly divide the bone into three regions. (1) The *costal* region, the thick transverse beam between the ends of the first pair of ribs, marked at the sides by the facet for the rib, occupying from a third to it may be nearly half the length of the bone. (2) The *pre-costal* region, occupying about the anterior fourth of the bone, thinning towards the cervical border. (3) The *post-costal* region, narrowing and thinning backwards, to end in a thickened tubercular peak. The costal region is the more essential one, completing the thoracic girdle, and varying only with robustness; the pre- and post-costal regions have muscular relations and are variable.

The following Tables give the chief measurements on which the descriptions are founded. Table I., the lengths and breadths of the two specimens. Table II. the thickness of each specimen at the several parts, at the mesial beam and on the right and left sides, with the breadth of the costal facets. Table III., the measurements of the costal facets on the two specimens.

The figures in the plate (Plate XIV.) show the form of the two specimens, as seen on the under surface and from the side. Fig. I., of specimen No. I.; fig. I*a*., of the right side of the same; fig. II., of specimen No. II.; fig II*a*., of the right side of the same.

These figures and the measurements given in the Tables, show the differences in form and thickness between the two specimens, and the frequent a-symmetry on the right and left sides of the same sternum.

TABLE I.—*Giving, in inches, the lengths and breadths of specimens No. I. and No. II. of the Sternum of the Greenland Right-Whale.*

Lengths and Breadths.	No. I.	No. II.
Total length, mesial,	27	25½[1]
,, ,, mid-lateral,	26	26½
Length of pre-costal region, mesial,	7¼	6½
,, ,, costal region, ,,	9¼	11¼
,, ,, post-costal region, ,,	10½	7¾
Breadth in front of costal facets,	19½	21¾
,, at anterior end of costal facets,	19	22
,, at broadest part of costal facets,	16½	17½
,, at middle of sternum,[2]	15½	17½
,, at posterior end of costal facets,	13	13
,, at middle of post-costal region,	6½	7½
,, at middle of terminal peak,	5¼	5¾

[1] Somewhat worn here. Probably ½ to 1 inch more.
[2] Same point as the preceding in No. II., 3 inches behind the preceding in No. I.

TABLE II.—*Giving, in inches, the thickness of sternum No. I. and sternum No. II., at successive stages backwards; taken at the middle line, at half-way to the sides, and at near the sides; and giving the breadth of the costal facets on the sides of the bone, right and left.*

Measurements of Thickness.	Specimen No. I.							Specimen No. II.						
	Mesial.	Mid-lateral.		Near the side.		Costal facets. Breadth.		Mesial.	Mid-lateral.		Near the side.		Costal facets. Breadth.	
		R.	L.	R.	L.	R.	L.		R.	L.	R.	L.	R.	L.
An anterior border, ...	$\frac{3}{4}$	worn	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	...	...	worn	worn	$\frac{1}{4}$	worn	$\frac{3}{4}$	...	...
At middle of pre-costal region, .	$1\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{8}$	1	$1\frac{3}{4}$	...	...	$2\frac{1}{2}$	$2\frac{1}{8}$	2	$1\frac{3}{4}$	$1\frac{3}{4}$	...	...
Between anterior ends of costal facets,	$2\frac{3}{8}$	$1\frac{3}{4}$	2	$1\frac{5}{8}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{4}$
Between broadest part of costal facets,	$2\frac{1}{4}$	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{1}{4}$	3	$2\frac{1}{4}$	$2\frac{5}{8}$	$3\frac{1}{8}$	$3\frac{1}{4}$	3	$3\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$3\frac{1}{4}$
At middle of sternum, ...	$1\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{3}{4}$	2	$1\frac{3}{4}$	$1\frac{3}{4}$	same	same	part	same	part	same	part
Between posterior ends of costal facets,	$1\frac{3}{8}$	$1\frac{1}{8}$	1	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	part $2\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{4}$
At middle of post-costal region, .	$1\frac{1}{8}$	1	$\frac{7}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	...	...	2	$1\frac{3}{4}$	1	$\frac{5}{8}$	$\frac{3}{4}$	...	...
At middle of posterior half of post-costal region, . . .	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	...	...	$2\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{5}{8}$	...	...
At 1 inch from posterior end, . .	$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	1	1	...	...	2	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	1	...	...
At posterior border, ...	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	...	...	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{5}{8}$	...	...

TABLE III.—*Giving, in inches, the measurements of the Costal Facets on the two sterna.*

Costal Facets. Lengths and Breadths. Right and Left sides of each.	No. I.		No. II.	
	R.	L.	R.	L.
Length, obliquely along the side, . . .	9	10	12½	11½
,, Of this, behind the broadest part, .	6	5½	6	4½
Breadth near anterior end, ...	1¼	1¼	2½	2¼
,, at midway anterior to broadest part, .	2	1¾	2¾	2½
,, at broadest part, ...	2¼	2⅝	3¾	3¼
,, at midway behind broadest part, .	1¾	1¾	1¾	2
,, near posterior end, ...	½	½	¼	¾

These two sterna are evidently adult and full sized. The lengths and breadths of the three mentioned by Eschricht and Reinhardt are, that from a 44½-feet-long individual 20 inches by 19; of another, 24 × 19; of a third, 23 × 16½. That of the 46-feet-long female skeleton in the London College of Surgeons Museum, above referred to, measures 22 inches by 20. As seen in Table I., these measurements in my No. I. specimen are 27 inches by 19½, those of No. II. 25½ inches (to the side 26½) by 22. No. I. shows the curvatures best and I take it for description first, noticing No. II. afterwards with comparison.

(A) SPECIMEN NO. I.

General a-symmetry.—A line (fig. I., *a*, *b*) drawn from the middle of the cervical peak, along the prominent "mesial" beam of the bone, to the middle of the posterior peak, shows the left side on most of the bone to be broader than the right. The excess on the left side is, at the anterior end of the costal facets (line *a*, *c*, *f*, on the figure) 1 inch; at the middle of the sternum (line *m*, *s*) 1¼; at the hinder end of the costal facets (line *p*, *c*, *f*) 1½ inches. Behind this point the excess lessens on the left and then changes sides, so that at the middle of the post-costal region the right side is now the broadest, by ¾ inch, and continues to be so to the end. Other particulars of a-symmetry will be noticed with the several regions.

(1) *Pre-costal region.*—As seen in fig. I., the *anterior border* advances inwards to a prominent rounded median peak, giving

7½ inches as the mesial length of the region, more than ¼ of the length of the bone. The curvatures of the border, vertically, are seen on viewing it from before. At and near the median peak, it is bent, concave above, convex below; then outwardly bent in the opposite direction, convex above, concave below; giving a concavity above of 2 inches, taken from the level of the sides. As seen in Table II., the border is thick at the median peak (¾ inch), thin at midway out (¼ inch on left side, worn on right side), and thickens (right side ½ inch, left ¾ inch) where it meets the much thicker lateral angle of the bone.

The *lateral angle* of the bone deserves particular notice, being the part where the great difference in form of the pre-costal region in No. II. originates. Here, in No. I., the angle is a-symmetrical, as seen in fig. I. On the *left side*, the angle proper, indicated by the thickness at the part (1¾ inch behind, 1¼ in front) and by the curve, is about 2 inches in length, measured straight; and it is more rounded, or shoulder-like, than on the right side. The angle on the *right side* begins 1½ inch sooner behind, is 4 inches in length, is less rounded than on the left side, and the bone is thinner (1½ inch behind, 1¼ at the middle, ¾ in front) and much rougher than on the left side. The anterior border of the bone, as seen in fig. I., undulates, convex on its outer half, concave on its inner half; in contrast with the left side which rises from the angle to the median peak with a uniform convexity. There is, thus, on the right side an approach to the formation in No. II., that of a prolongation forwards of the side of the bone from the lateral angle, with concavity between an antero-lateral angle and the median peak. The greater thinness of the bone at this part on the right side is notable in connection with its greater extension forwards.

The peculiarities of the *pre-costal region*, as compared with the costal region, are, its thinness, becoming thinner and thinner forwards; its greater transverse curvature; and the mesial beam bent downwards at the anterior median peak. The curvatures on the surfaces, to be noted with the surfaces, follow those of the anterior border just described.

(2) The *costal region* is marked off by lines drawn across between the ends of the articular facets (*a, c, f,* and *p, c, f,* fig. I.).

Length, 9¼ inches mesially, which is a little over a third of the entire length of the bone. This region is characterised by its great thickness, both at the mesial beam and at the sides, until near the narrow hinder end of the facets, as seen by the measurements in Table II. The continuation of the thickness out to the sides, the thickened arms of the ideal cross, modifies the curvatures on the surfaces at this region, to be noted with the surfaces.

The costal facets. Position.—Although the position of the part by which the sternum articulates with the ribs is indicated generally in looking at the under or upper surface of the bone, seen as more or less undulating shallow notches, their true length can be seen only on viewing the sides of the bone, as in fig. I *a*. In this sternum, they begin just behind the lateral angle of the bone, but behind there is no depression or projection to indicate their termination on viewing the under or upper surface of the bone. [See difference in fig. II.] The following is the position of the facets, longitudinally, on the bone. Posterior ends go behind middle (line *m*, *s*, fig. I.), the right for 3 inches, the left for 2½; anterior ends are a little behind anterior fourth of bone; broadest part of facets is in front of the middle of the region, most so on the right side; narrowing posterior part of facets is opposite hinder third of the region. As the right facet, shorter by an inch than the left, begins 1½ inches later and goes back ½ inch further than the left, the lines (*a*, *c*, *f*, and *p*, *c*, *f*, fig. I.) marking off the costal region are not quite transverse.

Direction of the facets.—Placed along the sloping sides of the bone, they necessarily slope towards each other backwards (19 inches apart in front, 13 inches behind). Vertically, they occupy at most parts nearly the whole thickness of the side of the bone, may at some parts round a little so as to be seen on the surfaces of the bone, and their surface may be rectangular to the surfaces of the bone or more or less bevelled. Here, on the right side, the facet is much bevelled to the under surface, so that on viewing the under surface of the bone, the facet is seen in its whole length (as in fig. I.) and for ¾ of its breadth; the remaining ¼, at the broadest part, being bevelled, or rounded, towards the upper surface, and seen in that view. On the left

side there is very little bevelling, scarcely any towards the under surface, and to the upper surface about $\frac{1}{4}$ of the breadth along the anterior third of the facet.

Form of the facets.—Table III. shows the breadth at the several parts, and the lengths, and that there is considerable asymmetry in both respects. Left, 1 inch longer than right. General form, that of an ellipse with undulating margins; broad on anterior $\frac{2}{3}$, narrowing on about posterior $\frac{1}{3}$, very narrow on about posterior $\frac{1}{8}$. They are marked off by a definite border, as well as distinguished by the appearance of the articular surface. At the anterior end it requires some care to distinguish the limit, but the characters of the surfaces show it. Immediately in front, where the edge of the bone rounds off from the side to the anterior border, at the lateral angle above described, the border is very thick and rough, having the appearance of bone where it attaches strong ligamentous bundles. The greatest breadth of the facets is at junction of anterior and middle thirds on right side, near the middle on left side, and is gained by bulging in the upward direction, as seen in fig. I *a*. The upper surface of the bone is thereby rendered very concave at this part. From this projection upwards it results that, when the bone is laid on the table on its upper surface, it rests laterally on this upward projection.

The *surface of the facets* is irregular, and is rough except on about its upper $\frac{1}{4}$ and on the narrow posterior end. These rougher and smoother parts remind one of the difference presented at the human sacro-iliac articulation by the auricular surface when denuded of its thin plate of cartilage and the rougher ligamentous area above it; but, on the whole, the surfaces of these facets suggest bone that has attached ligamentous tissue, not bone that has been covered by cartilage. In my 64-feet-long B. musculus, above referred to, as shown in the figure there given, each angle of the deeply excavated end of the rib and the end of the wing of the sternum at the outer articulation were tipped with cartilage, but there was none on the body of the sternum, the connection being by ligament only, $\frac{1}{2}$ inch in length and allowing of free movement.

(3) *Post-costal region.*—This region (fig. I., from line *p*, *c*, *f* to the end) presents a natural division into two stages, of nearly

equal length; *anterior stage* triangular in outline, narrowing backwards, now thinner at the mesial beam, and thinning greatly from the mesial beam outwards to the more or less sharp undulating edges; *posterior stage*, thicker both mesially and laterally than the anterior, thickened and very rough on the under surface of its posterior half, terminating in a thick-bordered blunt semilunar end.

The a-symmetry, already referred to generally, is very marked on the post-costal region, the greater breadth to the left side on the anterior stage, to the right side on the posterior stage. There has been some wearing of the left border of the anterior stage, opposite the dotted line in the figure. The beginning of the posterior stage is marked, just below that part, by a deep notch, giving the appearance of a neck to the peak beyond. The thickened semi-lunar, or semi-oval, terminal peak, $5\frac{1}{2}$ inches in breadth, about $4\frac{1}{2}$ in length, appears inclined to the left. The borders of the anterior stage are thin and do not seem as if they had attached strong fibrous structures, but the thickness of the terminal peak, mesially, laterally, and on the borders, as seen in Table II., and the roughness on the last $\frac{2}{3}$ of its under surface, indicate the attachment of strong fibrous structures there.

Curvatures on the Surfaces of the Sternum. (*a*) *Upper Surface. Transversely.*—The surface is concave on the anterior $\frac{2}{3}$, then flat, and, finally, on the terminal peak, convex. The concavity is great on the anterior half, greatest at the most projecting part of the border of the facet. The depths are, at middle of pre-costal region, 1 inch; at back part of that region, $\frac{3}{4}$ inch; on costal region at most projecting part of the facet, $1\frac{1}{4}$ inches; at back part of that region, $\frac{1}{2}$ inch; on anterior third of post-costal region, $\frac{1}{4}$ inch, then ceases.

Longitudinally.—The surface is convex on anterior $\frac{4}{5}$, to near middle of post-costal region; then concave (depth $\frac{1}{4}$ inch); finally convex on terminal thickened peak. The convexity is most marked on the pre-costal and costal regions, giving an elevation of $\frac{3}{4}$ inch at the middle of that extent. Near each side of the anterior $\frac{1}{3}$, there is a longitudinal concavity (depth $\frac{1}{2}$ inch) owing to the upward projection of the border of the facet and the upward convexity of the outer part of the anterior border.

(*b*) *Under Surface. Transversely.*—This surface is convex

transversely on the whole length of the bone at and near the mesial beam, which is seen to rise as a smooth projection along the middle of the bone. The transverse convexity is continued across the bone on the post-costal region, owing to the gradual thinning to the borders, giving a convexity averaging 1 inch in height at the middle. But, owing to the thickness at the facets and at the angle of the bone in front of the facets and the downward concavity of the outer part of the anterior border, there is mid-lateral concavity on the costal and pre-costal regions. This concavity is very slight on the costal region, but marked (depth about $\frac{1}{4}$ inch) on the back part of the pre-costal regions. This is well seen on the pre-costal region on viewing the under surface from behind, when the pre-costal region appears to the eye as saddle-shaped. A line obliquely from the prominent median peak to the thickened angle of the bone, gives a concavity $\frac{1}{2}$ inch in depth.

Longitudinally.—Along the mesial beam there are four curvatures, as seen in fig. I *a*. (1) A minor concavity on the pre-costal region (depth $\frac{1}{8}$ inch) owing to the bending down of the anterior peak. (2) A marked elongated convexity, opposite the anterior $\frac{2}{3}$ of the costal facets, but beginning on the posterior $\frac{1}{3}$ of the pre-costal region; a length of about 9 inches, and giving an elevation of $\frac{1}{4}$ inch. (3) A major elongated concavity, extending from opposite the posterior $\frac{1}{3}$ of the costal facets (rather in front of the middle of the sternum) to beyond the middle of the post-costal region; a length of 9 inches, with a depth of $\frac{1}{3}$ inch. (4) The convexity on the rough terminal peak, about 4 inches in length; giving an elevation of nearly $\frac{1}{2}$ inch. Mid-laterally, these longitudinal curvatures on the mesial beam are, on the whole, followed, with some a-symmetry on the two sides.

Relation of the curvatures on the two surfaces to each other. Adaptations of the sternum.—The general *transverse* curvature of the sternum at its *costal* and *pre-costal* parts may be regarded as in adaptation to the general form of the thorax and the "neck" of this cetacean. The two surfaces have a general parallelism, concave above, convex below. The difference is one of degree. The excess of the upper over the lower curvature is owing to the greater projection of the upper edges of the articular facets. But the *longitudinal* curvatures are the reverse of parallel

opposite the costal facets and the thick angles of the bone in front of them, both being convex. This is effected by thickening of the mesial beam and the arms of the primary cross, in adaptation to the support and fastening of the first pair of ribs. Behind this, the bone, now free from the ribs, tapers off irregularly to a thick rough terminal peak, in relation apparently to the attachment of muscles.

(B) Specimen No. II., with Comparison.

This sternum, though scarcely so long, is broader, thicker and heavier, altogether more robust, than No. I., and from certain roughnesses may be inferred to have been that of a not merely adult but old individual. The following are the chief differences it presents from the characters of No. I., above described.

In thickness.—This is the great difference. On running the eye down the columns in Table II., the greater thickness is seen nearly everywhere.

A-symmetry.—They nearly agree in this respect, both broadest on the left side till the middle of the post-costal region is reached, then broadest on the right side. In No. II. the a-symmetry begins further back, not till opposite the anterior end of the costal facets, is greatest (1¼ inch) opposite the broadest part of the facets, and lessens backwards (1 inch opposite the hinder end of the facets). The excess on the left side is thus somewhat less than in No. I., but after the middle of the post-costal region the a-symmetry, the excess now on the right side, is as great (1½ inches) as in No. I. The terminal peak, as seen in fig. II., is inclined to the right side, which is its broadest side; that of No. I. to the left side, which is its narrowest side. The lines (*a*, *p*, figs. I. and II.) are drawn straight along the mesial beam to its elevated termination on the under surface of the peak.

It does not seem that a greater breadth on one side determines the position and length of the costal facets. It may seem to do so in No. I., in which the longer facet, the left, begins 1½ inches earlier and ceases ½ inch sooner than the right; but in No. II., the left facet is the shorter, begins ½ inch later (the a-symmetry just beginning) and ceases ½ inch sooner than the right.

In general form.—Comparing figures I. and II., it is seen that the anterior border of No. II. is concave, giving the heart-shape, with a rudimentary median elevation; while in No. I. the anterior border is convex, rising to a prominent rounded angle at the middle, converting a triangular form into a very unequal ovoid form.

While the two sterna are of about the same total length (27 and 26½ inches), No. II. is broader by 2¼ inches (19½ and 21¾). In Table I. it is seen that this greater breadth in No. II. is at all its parts, except at the narrow posterior end of the costal facets, and is most marked at the anterior part of the costal facets, where the difference is 3 inches.

As between these two sterna, it would appear that robustness carries with it greater breadth, but not greater length.

In the proportion of the regions.—As seen in Table I., the proportions of the regions differ, not much on the pre-costal region, but No. II. has a much longer costal region, by 2 inches (11¼, 9¼). This is mainly at the expense of the post-costal region which is 2¾ inches shorter than in No. I. (7¾, 10½). From this it appears that robustness brings with it increased length (as well as greater breadth and thickness) at the costal region; and that, whatever the use of the post-costal region in relation to the soft parts may be, it does not require length as an accompaniment of robustness.

From this greater length of the costal region in No. II., it follows that the middle of the sternum (fig. II., *m, s*) is further forward on that region than in No. I. (fig. I., *m, s*); being, in No. II., at about the middle of the region, and opposite the broadest part of the facet; in No. I., about 3 inches further back, opposite the junction of the middle and posterior thirds of the region, and still further behind the broadest part of the facets.

(1) *On the costal region.*—The *costal facets*, besides being longer, by about 2 inches, are also broader in No. II. until near their narrow posterior end, as seen in Table III. They agree in being a-symmetrical in both, but differ in that the longer facet is on the right side in No. II., on the left side in No. I. (In No. I., right 9 inches, left 10; in No. II., right 12½ inches, left 11½.)

But the chief difference between the facets in the two sterna

is in the direction in which the increase in breadth is gained at their broadest part. As seen in figures I*a*. and II*a*., the increased breadth is gained in No. I. towards the upper surface of the bone, in No. II. towards the under surface. This difference greatly alters the curvature of the borders of the respective facets. In No. I., the borders are both convex, the upper most so, giving an elliptical form; in No. II. the upper border is concave at the middle, the lower border very convex at the broad middle part of the facet and irregularly concave at the anterior and posterior parts. The position, longitudinally, of the broadest part of the facets differs in the two sterna, as seen in Table III. In No. I., the broadest part is in front of the middle, most so on the right side; in No. II., behind the middle, most so on the left side.

In regard to their direction vertically, the surfaces of the facets in No. II. do not present the marked bevelling, seen on the right facet of No. I. towards the under surface of the bone. In No. II. they are irregularly flat or a little convex vertically, and go round some way on the upper surface of the bone, so that they are seen on that surface for a breadth of 1 to 1½ inch at the anterior half, for ½ to 1 inch at the posterior half. They are not seen on the under surface of the bone except at their broadest part, where the left shows itself for a breadth of ½ inch, the right for 1½ inches, as seen in fig. II.

These bevellings towards, or roundings upon, the surfaces of the bone are of some interest in connection with the mode of articulation with the rib—the form of the end of the rib, the direction of the rib against the sternum, and the nature of the uniting medium. Unless occupied by intervening thickened cartilage or by fibrous tissue, these roundings towards the surfaces of the bone suggest vertical concavity of the end of the rib; but they are far from being symmetrical. In No. II., the surfaces of the facet are more irregular, the pits and elevations coarser, than in No. I.

(2) *On the pre-costal region.*—The sides advance more than the middle, giving the heart-shape to the sternum, and forming an anterior lateral angle besides the lateral angle common to both specimens. Between these posterior and anterior lateral angles, the border, 8 inches in length, is very thick (posteriorly 2½

inches, at middle 1¾, in front 1 inch), and is on its posterior ⅔ very rough, with mammillary projections like rough finger ends; on its anterior ⅓ less rough. This roughness suggests the attachment of strong fibrous structures. The difference here from No. I. is great, as in it the border does not advance to form an antero-lateral angle but is rounded off, the thick part (thinner than in No. II.) 2 inches in length on the left side, 4 inches on the right side, being on the latter an approach to prolongation to form an antero-lateral angle.

Viewed from before, the anterior border has a more uniform and deeper concavity upwards (2½ inches in depth, from the level of the anterior lateral angles) than in No. I., owing to the sides bending more upwards than in No. I. The anterior border is thin mid-laterally (¼ inch on left side, where it is not worn). At the middle there is a low projection, now worn in front; at the base, 2½ inches broad, 1 inch thick, and, as now worn, projecting ¼ inch. Judging by the thickness of the worn edge mid-laterally on the right, in comparison with the unworn edge on the left side, this projection may have had a length of ½ to 1 inch more, and thus have formed a projecting anterior peak. The inferior surface of the bone shows a rough triangular thickening (3 inches in length and equilateral) continued from the base of this rudimentary peak.

Some explanation of the variations that occur on the anterior border of the sternum of Mysticetus, as illustrated by these two specimens, may be found in connection with the muscular attachments there. The variation is not so great as that, above referred to, occurring on the corresponding part of the sternum in the Fin-whales.

(3) *On the post-costal region.*—The chief difference on this region is its shortness compared with that of No. I., already noted. In both, the region begins anteriorly with a breadth of 13 inches, but as the length in No. I. is greater (10½ inches) than in No. II. (7½ inches) the posterior part of the bone has a broader appearance in No. II. than in No. I., as seen in figures I. and II. At 7½ inches forwards from the end, the breadth of No. I. is but 10 inches. It is more robust throughout than in No. I., as seen in Table II. The borders are thicker (right ⅜ inch, left ½ inch; in No. I. sharp) and the marking suggests the

attachment of pretty thick fibrous structures. The elevation on the under surface of the terminal peak, continued from the mesial beam, is greater than in No. I. The peak, besides being broader on the right side and directed to that side, is there twisted upwards. The markings on the peak, especially on the under surface, suggest the attachment of very strong fibrous structures. The peak of No. I. is horizontal, directed to the left, and not so rough as in No. II.

In the curvatures on the surfaces of the bone.—The curvatures are the same, generally, as in No. I., but considerably modified by the presence of the antero-lateral angle, by the greater thickness at the costal region, and by the shortness of the post-costal region. (*a*) *Upper surface. Transversely.*—Differs in being much more concave on pre-costal region (depth 2 inches, in No. I., 1 inch), owing to prolongation of border to form an antero-lateral angle; much less concave on costal region (depth at middle $\frac{1}{4}$ inch, in No. I., $1\frac{1}{4}$) owing to border of costal facet not projecting here; and in being convex on the whole of post-costal region (elevation $\frac{3}{4}$ inch), while in No. I. post-costal region is still concave on its anterior $\frac{1}{3}$ and then flat. *Longitudinally*, while No. I. is convex on its anterior $\frac{2}{5}$, then concave and finally convex on the peak, No. II. is convex only on the pre-costal region, flat on the costal region, then concave (depth $\frac{1}{2}$ inch) to the end. These differences give a very different appearance to this surface of the bone in the two specimens.

(*b*) *Under surface. Transversely.*—The convexity is more marked than in No. I., except at the thickest part of the costal facets, which in No. II. projects most to this surface. The greater convexity on the pre-costal region is more at the sides, between the lateral and antero-lateral angles, than at the median beam. Mid-lateral concavity on pre-costal and costal regions less marked than in No. I., mainly from less projection of the median beam. *Longitudinally.*—The four curvatures along the mesial beam are the same as in No. I., but less marked; this especially on the major concavity (depth $\frac{1}{4}$ inch, in No. I. $\frac{1}{2}$ inch), owing to shortness of post-costal region. The longitudinal convexity is more marked on the sides all along precostal and costal regions in No. II. than along the mesial beam (more decidedly so than in No. I.), owing to the upward as well

as forward direction of the antero-lateral angle and the greater projection of the costal facets to this surface (see figs. I *a* and II *a*).

Thus, the curvatures of the sternum are not so simple as indicated in the passage above quoted from the valuable Memoir of Eschricht and Reinhardt on the Greenland Whale. I would not describe the inferior surface as longitudinally flat, nor apply the terms convex longitudinally and concave transversely to the whole length of the upper surface. The curvatures and other characters of the bone can be understood only by distinguishing the three regions into which I have divided it. Though modified by variation in the proportions of the three regions, by robustness, by the presence or absence of an antero-lateral angle, and by the costal facets projecting most either towards the upper or the under surface, the curvatures are the same in both these specimens and belong to the construction of the bone.

The differences noted between these two specimens are striking in their effect when the two bones are viewed lying together on the table. Laid on the *upper* surface, No. I. rests on the moderately bent-up posterior peak, and on the borders at the middle of the costal facets; the anterior peak of the bone raised 5 inches from the table. No. II. rests behind on the twisted-up right side of the terminal peak; in front on the rough border some way anterior to the costal facets, the middle of the facet raised an inch from the table; the rudimentary anterior peak raised only 3¼ inches from the table. Laid on the *under* surface, No. I. rests on the posterior and anterior peaks; No. II. rests on the costal region, the posterior and the rudimentary anterior peak each raised an inch from the table. The variations causing these differences in relation to a level surface are noted above. In viewing the two specimens thus laid together, from the side as well as from above and below, the curvatures above described and their modifications on the two bones are seen.

Roughnesses on the surfaces of No. II.—These roughnesses suggest some sub-periostitic action, but their direction indicates the line of attachment of ligaments or muscles. They occur as little tubercles from pin-head to particle-of-wheat size or as streaks. On the under surface of the costal and pre-costal

regions they are arranged in rows or as streaks across the bone (see fig. II.), suggesting the attachment of pectoral muscles, and, near the facets, of ligaments. On the upper surface they occur only near the facets, and suggest the attachment of ligaments. On the post-costal region, on both surfaces, they are directed obliquely to the sides, longitudinally towards and on the peak, indicating the attachment of longitudinal fibrous structures. But dissection of the soft parts alone can show what the muscular and ligamentous relations of the bone are.

Besides being more robust and rough, No. II. is heavier than No. I., weighing 20¾ lbs., No. I. weighing 17¼ lbs.

EXPLANATION OF PLATE XIV.

The figures, reduced to about $\frac{1}{10}$, are from photographs. Figs. I. and II., views of the inferior surface of the two specimens; figs. I*a*. and II*a*., the same viewed from the right side, showing the lateral border, and the inferior surface, *i, s*, obliquely as far as the middle line. *a, p*, line drawn along the mesial beam of the bone, from *a* the anterior to *p* the posterior peak; *m, s*, line drawn across at middle of sternum; *c, f*, costal facet; *a, c, f*, at anterior end of costal facet; *p, c, f*, at posterior end of costal facet. The costal region is between the dotted lines *a, c, f*, and *p, c, f*; the pre-costal region, all in front of *a, c, f*; the post-costal region, all behind *p, c, f*.

The frames enclosing figs. I. and II., of the same length and breadth, show the difference in length and breadth of the two specimens, and assist the eye in recognising the differences in form. The a-symmetry is seen in both, the left side broader than the right. The short dotted line on fig. I. indicates a worn part of the left border. The direction of the roughnesses near the costal facets and near the posterior end, described in the text as occurring on specimen No. II., are seen in fig. II.

Figs. I*a*. and II*a*. show the differences in thickness of the two specimens; the different direction in which the costal facet gains breadth, to the upper surface in fig. I*a*., to the inferior surface in fig. II*a*.; the longitudinal curvatures on the inferior surface of the bone, four in number, two concavities and two convexities, best marked in fig. I*a*., the thinner bone; and the concavity on the upper surface of the bone behind the costal facets. The greater length and thickness of the rough border in front of the costal facet in fig. II*a*. is seen, the bone in it extending forwards to form an antero-lateral angle.

EDINBURGH, *June 1895.*

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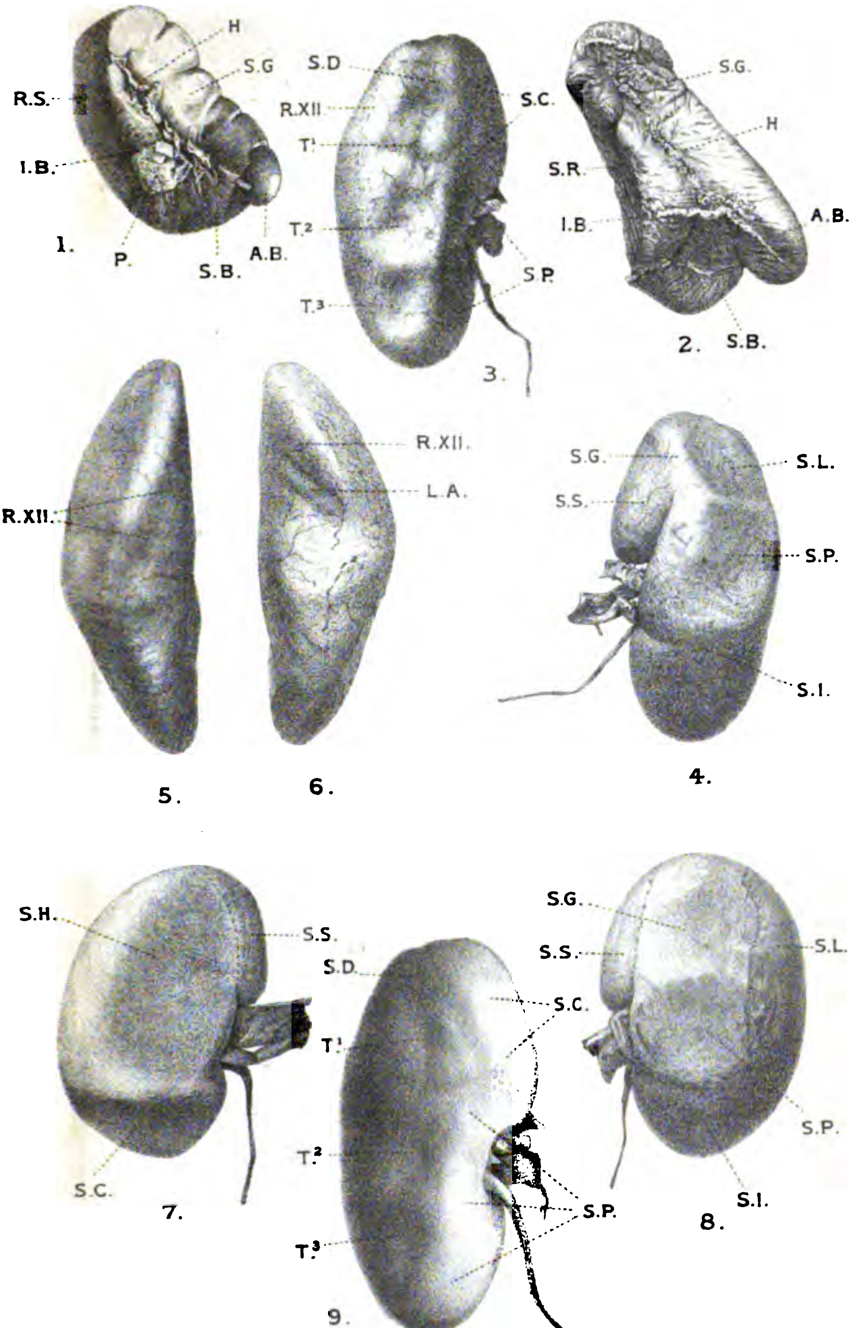

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SPLEEN AND KIDNEYS.

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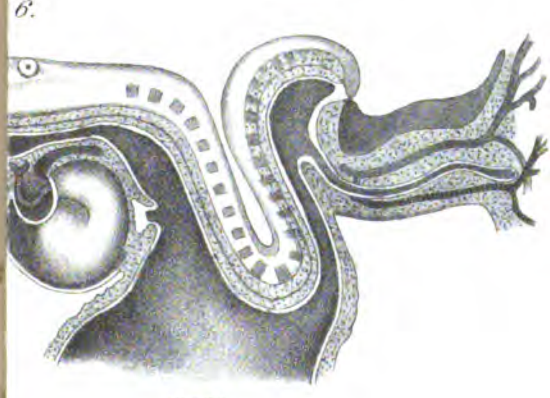

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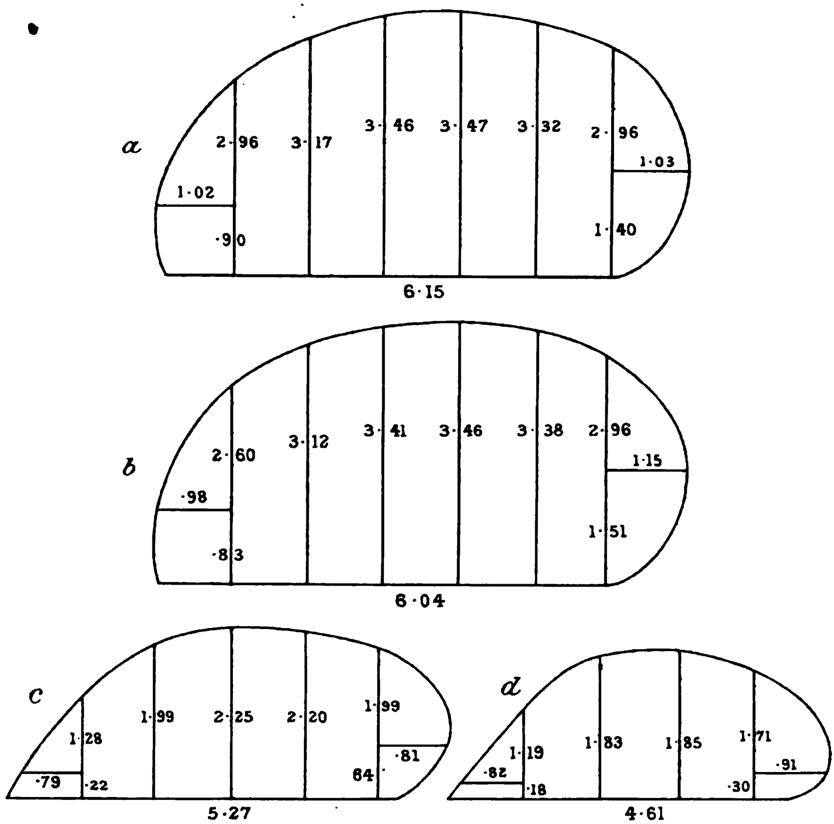
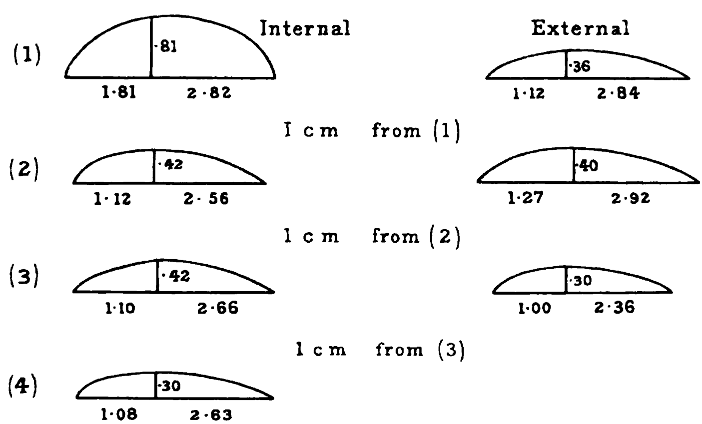
COMPARISON OF THE ARTICULAR SURFACES.



Internal Articular Surface. External Articular Surface.

TRANSVERSE CURVES OF HORIZONTAL PART OF ARTICULAR SURFACES



Immediately behind the Semilunar Depressions.

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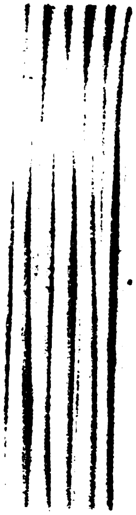

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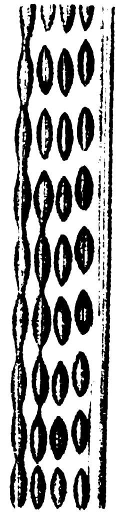

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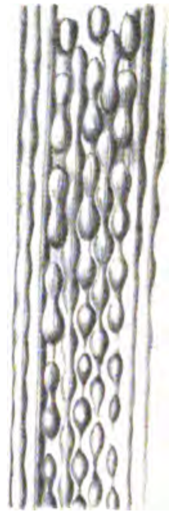

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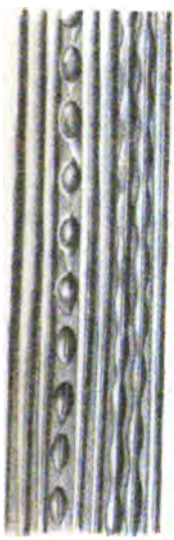

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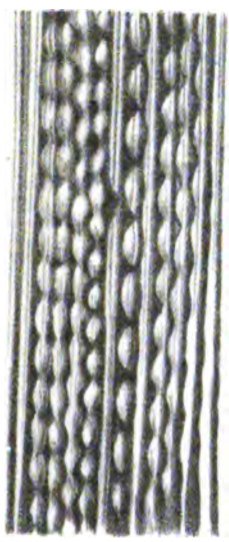

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TONE & CURVES OF PHONOGRAPH

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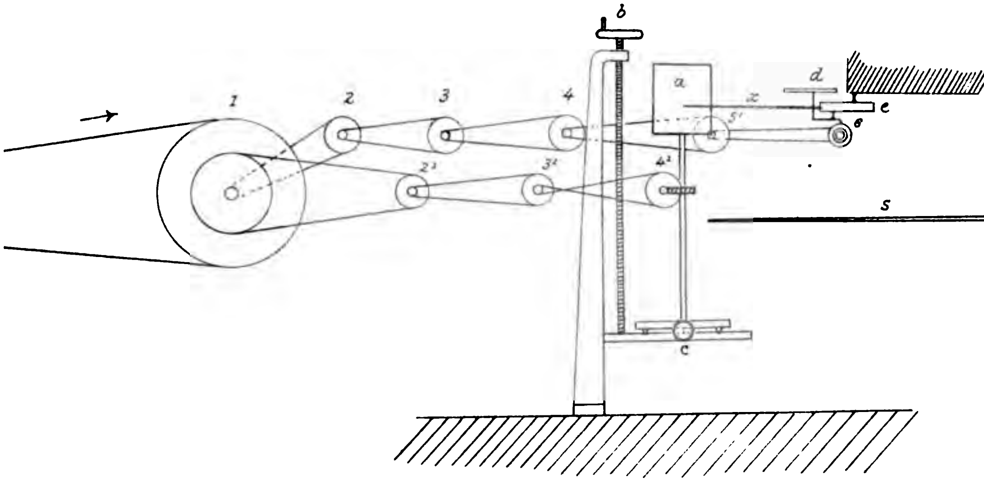
Fig. 1.



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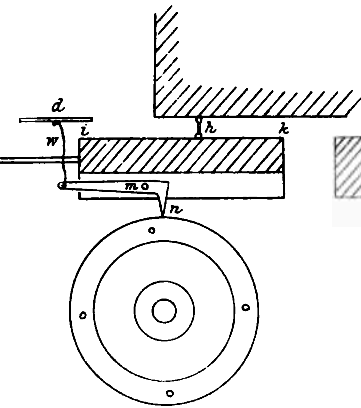

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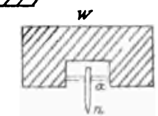

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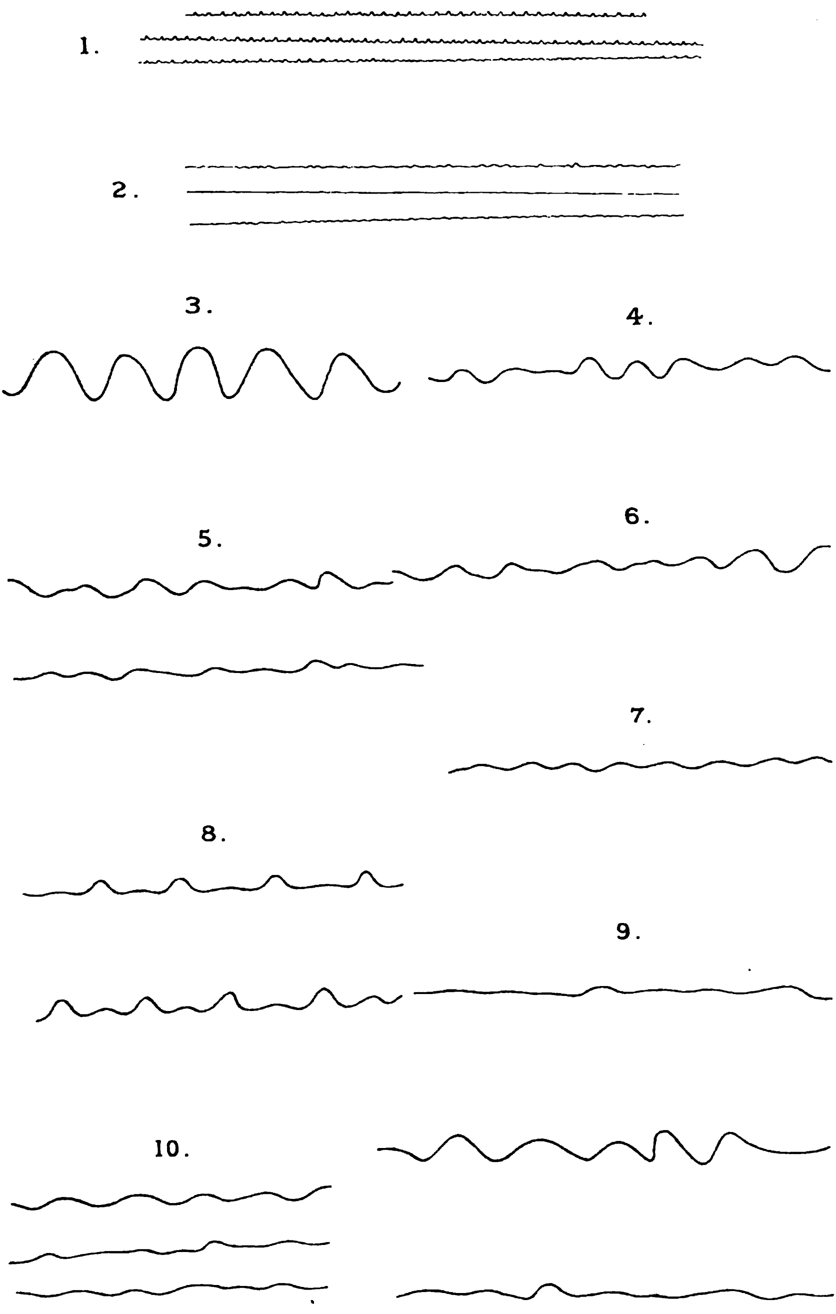

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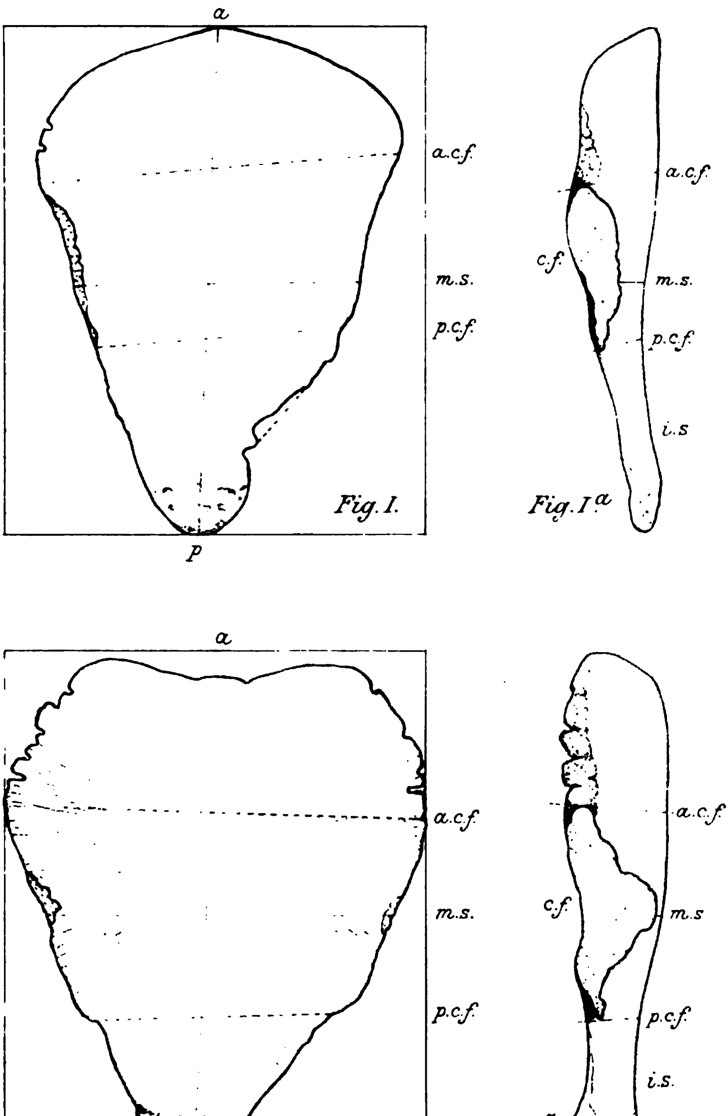


John Struthers del — Reduced to $\frac{1}{10}$ — F. Huth, Lith.r Edin.r

STERNUM OF GREENLAND RIGHT-WHALE.
BALAENA MYSTICETUS.

PROCEEDINGS OF THE

ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

NOVEMBER 1894.

THE Annual General Meeting was held on Monday, November 19, at the London Hospital Medical College. Present—Professor D. J. CUNNINGHAM (President) in the chair, Sir G. M. HUMPHRY (Past-President), thirty-five members and visitors.

The minutes of the previous meeting were read and confirmed.

The following gentlemen were nominated for membership:—Christopher Addison, M.D., B.S., proposed by Mr Lockwood, Mr Bruce Clark, Dr Shore; Dr St George Mivart, F.R.S., proposed by Professor G. B. Howes, Sir George Humphry, Percy Flemming; H. N. Weir, F.R.C.S., proposed by Mr W. M'Adam Eccles, Mr Lockwood, Percy Flemming.

The HON. TREASURER presented his Annual Report, showing a balance in hand of £49, 8s. 11d. In presenting his report, Professor HOWES remarked that the balance in hand—which was largely due to the recovery of subscriptions in arrear—was half bespoken for the compilation of an index to vols. xxi. to xxx. of the *Journal of Anatomy and Physiology*, which the Society's Committee of Management had ordered to be put in hand, and for the purchase of members' copies of the same when printed. He said that he regarded with greatest alarm the small expenditure of the year on the Society's publications. The fact that during that period, in contradistinction to the two years which preceded it, the enrolments numerically exceeded the resignations, showed that that which he regarded as a deficiency of output was not due to any falling off in numbers. The Society was in a financially healthy condition, and in a position to extend and to improve the character of its Proceedings.

Mr BLACK, who acted as scrutineer, reported that the following gentlemen had been unanimously elected as officers for the ensuing session:—*President*—Dr J. Cunningham, F.R.S. *Vice-Presidents*—William Anderson, John Cleland, F.R.S.; Charles Barrett Lockwood. *Treasurer*—G. B. Howes. *Secretaries*—Ambrose Birmingham, M.D. (Ireland); J. Yule Mackay, M.D. (Scotland); Percy Flemming (Eng-

land). *Council*—H. St John Brooks, Alexander Hill, M.D.; Robert Howden, M.D.; A. A. Kanthack; R. Clement Lucas, M.S.; Alexander Macalister, F.R.S.; G. H. Makins; T. H. Openshaw, M.B., M.S.; F. G. Parsons; A. M. Paterson; R. W. Reid, M.D.; Arthur Robinson, M.B.; H. D. Rolleston, M.D.; C. S. Sherrington, F.R.S.; T. W. Shore, M.D.; Johnson Symington, M.D.; J. H. Targett; Arthur Thomson; G. R. Turner; Bertram Windle.

Mr F. G. PARSONS showed a specimen of *Absence of the Extensor Primi Internodii Pollicis*, accompanied by loss of movement of the metacarpo-phalangeal articulation. This condition, he stated, was present in both hands, and he was doubtful whether to regard it as a coincidence, or as cause and effect. If it were to be regarded as the latter, he suggested that the absence of the extensor muscle had led the subject during life to involuntarily avoid flexing the joint beyond a very slight amount, and that, owing to disease, the dorsal part of the capsule of the metacarpo-phalangeal joint had shrunk, so that flexion of the joint beyond a very slight amount was impossible.

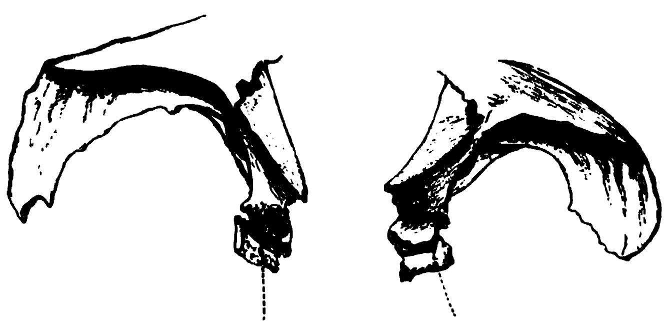
Prof. D. J. CUNNINGHAM and Dr TELFORD SMITH gave a lantern demonstration of the anatomical characters of two *Brains of Microcephalic Idiots*. One of these weighed 352·3 grammes, and the other 559·5 grammes. The former is, therefore, one of the smallest fully adult male brains on record. Reference was made to Giacomini's work in this field, and his classification of microcephalic brains into (*a*) those which belong to the domain of pathology, and (*b*) those which present certain common morphological features, and which are free from pathological taint, was accepted. The two brains exhibited belong to the latter subdivision. Both present a quadrupedal condition in so far as the relationship between the cerebrum and cerebellum is concerned. In both the occipital lobe has aborted, and the parietal lobe is small. With these quadrupedal characters there is associated a profound convolutionary disturbance. This takes a somewhat different form in the two brains. In the larger brain the fissures and convolutions are arranged partly according to a Simian plan, and partly in accordance with a human fœtal plan. In the smaller brain Simian features predominate, and these resemble in some of the gyri and sulci a condition distinctive of a low ape, and in others peculiarities characteristic of a man-like ape.

The whole question presents an exceedingly difficult problem for solution; but, in the case of true and typical microcephalic brains (such as those demonstrated), the authors, whilst repudiating Vogt's arguments, were inclined to accept, with some reservations, his hypothesis. Put shortly, this hypothesis may be stated thus: that microcephaly consists in a partial atavism of the brain, in which a phylogenetic stage in the development of that organ is reproduced.

R. CLEMENT LUCAS read a paper *On an Undescribed Groove on the Inner Side of the Spine of the Sphenoid, formed by the Chorda-Tympani Nerve.* It is the custom to offer an apology for putting on record a

new anatomical observation which cannot be shown to be of any great practical importance, or to which no interesting theory can be attached. This practice is much to be deprecated, since it indicates a feeling that unrecorded knowledge in anatomy requires to be bolstered up by surgical use, or be made of interest by supposing it to be a special design in nature of uncommon import before it can be received or adopted on its own merits. Happily we have escaped from the time—some thirty years ago—when, disregarding all the teaching of development, all the modifications by use, or of decay from disuse, examiners, inventing puerile theories of their own, expected students to attach these ridiculous romances to some anatomical fact before candidates for degrees could be approved for their profession. Perhaps the climax of absurdity in that era was reached when, as I can vouch, one examiner used to demand of students why the sheath of the rectus muscle was deficient behind at the lower part, and expected them to answer that it was to allow the muscle, during contraction, to dip into the pelvic and assist in emptying the bladder; and another would ask what dislocations of the hip-joint the feeble vascular, so-called ligamentum teres, was designed to prevent. These misconceptions and misinterpretations of nature's work added merely useless lumber to anatomical knowledge. I make no apology, therefore, for bringing forward a small anatomical fact which I believe has hitherto been passed by unnoticed. Should it make more clear, precise, and definite the course of an interesting nerve, that alone, I would maintain, is sufficient to make it worthy of record.

The position of the canal of Huguier, by which the chorda tympani escapes from the temporal bone, is never very clear to a student, because its external aperture is lost in the recess between the squamous and petrous portions of the temporal bone at the extreme inner end of the Glaserian fissure. Asked to indicate the position of this aperture



on an articulated skull, a candidate will almost invariably point to the Glaserian fissure external to the spine of the sphenoid, some quarter of an inch too far out, whereas the nerve can be easily shown to lie in contact with, and to groove, the inner side of the sphenoidal spine. To point out this important relation, of which I can find no mention, is the object of this short communication.

The groove can be readily found on the inner side of any well-developed sphenoidal spine, a little posterior and internal to the foramen spinosum. It is from a quarter of an inch to three-eighths of an inch in length, and is directed from behind downwards and forwards. In its course it frequently presents a slight concavity directed forwards, and at its lower limit there is often a notch in the edge of the spine. In one specimen, which I show, the edges of this notch have so far grown towards each other as to form an almost complete foramen, just behind the foramen spinosum. In another, the course of the nerve is indicated by a canal, which actually perforates the spine, and opens up as a groove only at its lower edge. The groove is more or less pronounced relatively to the greater or lesser development of the sphenoidal spine, which is a part liable to considerable variation; but there are comparatively few spines on which some evidence of the groove cannot be detected. The diameter of the groove corresponds to that of the slender nerve which it supports, but it may be noticed in certain instances to widen toward the lower part, as if the nerve were here subjected to a certain amount of movement. Considering that the chorda tympani soon applies itself to the lingual nerve, and that this attaches itself to so movable a part as the side of the tongue, it is not to be wondered that some trace of this transmitted mobility should find record on the bone, though the general tendency of the bony support will be to limit mobility and afford protection against muscular pressure.

In many of the sphenoids examined the nerve may be found dried and caked in the groove with the bleaching material used in preparing the bone.

In an articulated skull the guide that best leads to the position of the groove is the tubercle at the anterior extremity of the vaginal process of the temporal bone, just in front of the carotid canal. This projection of bone is immediately behind the groove on the sphenoid. If a name be required for descriptive purposes, perhaps "stria spinosa" or "sulcus spinosus" might be used, to bring the nomenclature into harmony with the term foramen spinosum, given to the aperture for the middle meningeal artery.

The following paper by Professor WINDLE, on *The Cusps of the Pulmonary and Aortic Valves*, was taken as read:—

The following brief note is based on the examination of the valves of the pulmonary and aortic orifices in nearly one hundred cases. The number has been made up to the full total of one hundred by the notes of the position of the cusps in frozen sections, kindly given me by Professors Birmingham, Cunningham, Reid, Symington, Thomson, and Turner. The object of the observations was to determine the relative positions occupied by the cusps, since marked discrepancies occur in the text-book descriptions. Valsalva's description, followed by some books, places the cusps of the pulmonary orifice as one anterior and two posterior, and those of the aortic as two anterior and one posterior. The other description, called by some Gibson's, though I know not if he were first responsible for it, places the cusps in a

manner exactly opposite, viz.:—pulmonary, two anterior and one posterior; and aortic, one anterior and two posterior. In examining the vessels—a task in which I have been much assisted by several of my prosectors, and notably by Mr Bennett—great care was taken not to disturb the position of the arteries. With this intent, a window was made in each immediately after the sternum had been removed, and before any dissection of the pericardium or great vessels had been undertaken. The result of the observations shows that Valsalva's description is correct in 15 and Gibson's in 85 of the 100 observations. In saying this, however, it is important to note that the description is only a rough one. It is only in comparatively few cases that the two anterior cusps of the pulmonary artery are equally anterior, *i.e.* that the point of conjunction of their contiguous edges is accurately in the centre of the anterior aspect of the vessel; and the same is true of the two posterior cusps of the aorta; indeed more true, for the arrangement in the pulmonary orifice tends to be more strictly in conformity with the description than that in the aortic.

I have not as yet been able to determine whether the shifting of the point of contact is due to an alteration in position of all the cusps at the same time, or to mutual and complementary variations in length of the contiguous pair, whether anterior or posterior. I think that the latter is the correct explanation, but I hope to be able to determine this, as also the site of the cusps, with greater exactness in a fresher series of observations. I should just mention that the results obtained from the frozen sections alone do not differ materially from those based on the ordinary method of dissection. I have notes of seven aortic and six pulmonary arteries, of which all the latter and five of the former follow Gibson's description, one only aorta conforming to that of Valsalva.

The following paper by Mr HIGGENS, on *The Varieties of the Posterior Crucial Ligament of the Knee-Joint*, was taken as read:—

Certain of the ligamentous structures of the knee-joint seldom accord with the conventional descriptions found in the text-books. In the course of the dissection of nearly forty joints, I have noted the variations in arrangement met with; and in this paper I propose to describe those found in the formation and connections of the posterior crucial ligament.

In future papers I hope to continue this record of variations by describing the different forms of the popliteus tendon and its accessory tendon slips, the semi-lunar cartilages, and the capsule of the knee-joint.

A conspicuous and constant feature of the posterior crucial ligament is the presence of an oblique band, which, as it is mentioned and figured by Humphry in his treatise on the Human Skeleton, I have ventured to name "Humphry's Ligament."

In order to appreciate some of the varieties of the posterior crucial ligament, it is necessary to observe the exact form of the femoral intercondylar space.

In the commonest condition of this region, it presents an inner, an

outer, and an antero-internal surface. It is separated from the articular surface by a prominent rim, which is angular at the junction of the surfaces.

Next to the rim on its inner surface is found a well-marked groove, deepening into a conspicuous elongated depression. To this is attached the oblique portion of the posterior crucial ligament.

The posterior crucial consists of two structurally and functionally distinct divisions—

1. The anterior straight fibres.
2. The posterior oblique fibres.

The straight fibres are attached to the femur, to the anterior half of the inner surface, and a considerable proportion of the antero-internal surface close to the rim, sometimes actually touching the anterior crucial, which is limited anteriorly by the angle joining the outer and antero-internal surfaces.

The tibial attachment is to the interarticular space anterior to the attachment of the oblique fibres, and either by the side of, or posterior to, the posterior cornu of the external semi-lunar cartilage.

These fibres are frequently much stronger and more numerous than those of the oblique portion. (In about 80 per cent.)

The oblique fibres are attached behind and internal to the anterior, mainly to the depression on the internal surface of the intercondylar space.

The two divisions are usually disposed with regard to each other, so as to form a continuous band. In one of my specimens, however, a rounded bundle of the oblique fibres is found lying on the other fibres, simulating the disposition of Wrisberg's ligament. The fibres spread out in their passage downwards and outwards; those that are hindmost at the femoral attachment being the highest, and the most external at the tibial.

Their tibial attachment is to the smooth surface between the tuberosities, the more superficial fibres being continuous with the periosteal ligaments and with the posterior superior tibio-fibular ligament. This is by far the most variable part of the ligamentous apparatus of the joint; it generally receives contributions from the neighbouring structures, and it is remarkably variable in strength and disposition. The functions of the two parts of the ligament present several points of interest.

When extension of the joint approaches completion, the outermost oblique fibres, which are attached hindmost on the femur, are the first to be made tense; with more perfect extension, it becomes necessary for the femur to rotate inwards, till the relatively short innermost fibres are made tense. As the latter are attached more anteriorly than the former, they render necessary a coincident gliding backwards of the inner condyle.

The tension of the outermost oblique fibres, the anterior crucial, the lateral ligaments, and the greater weight on the outer condyle, tend to limit the movement of the outer half of the joint, and to keep it comparatively fixed.

I hope to give a further discussion of these movements in another paper.

The straight fibres are only made fully tense on extreme flexion of the joint.

The posterior crucial may receive the following series of fibres from neighbouring structures :—

(1) From the popliteus. The contingent from this source may come from that portion of the muscle connected with the ligamentum posticum Winslowii, or from the tendon itself.
(2) From the fibula, by a series of fibres, either superficial to, or deeper than, the popliteal tendon.
(3) From the short external lateral ligament.
(4) From the external semi-lunar cartilage, either—
  (α) posteriorly, as Wrisberg's ligament;
  (β) anteriorly, as Humphry's ligament.
(5) From fibres which are continuous with those of the posterior superior tibio-fibular ligament.
(6) From fibres continuous with the periosteal ligaments.
(7) From the capsule, or from the coronary ligaments.
(8) From fibres which pass in a looped manner from the femur near the insertion of the popliteus.
(9) From the posterior cornu of the internal semi-lunar cartilage.

(1 and 2) *Fibres in connection with the Popliteus and the Fibula.*—There are, in most specimens, some fibres contributing to the oblique portion of the posterior crucial, derived from—

(A) The tendon of the popliteus; or
(B) That part which is occasionally attached to the ligamentum posticum Winslowii; or
(C) Fibres passing from the fibula, either deep or superficial, to the tendon, to which they may be firmly attached.

The following are the chief dispositions of these fibres :—

(1) They may be mixed with some irregularly disposed fibres on the outside of the posterior crucial, and attached to it immediately under the ligamentum posticum Winslowii.
(2) They may run horizontally into the oblique portion, being very tightly bound down at the angle of junction, and then continued upwards and inwards with the oblique crucial fibres.
(3) They are usually connected with the fibres derived from the short external lateral ligament.
(4) In some specimens Wrisberg's ligament is found to be connected with the fibres of the popliteal tendon, and frequently with those which are attached to the fibula.
(5) In one specimen some fibres which, from their femoral attachment apparently represent Wrisberg's ligament, are only connected below with the tendon of the popliteus, to which they run at right angles.

(3) In three or four specimens fibres were found attached to the short external lateral ligament on its anterior and internal side. Though well marked, these are neither strong nor numerous. They frequently blend with those fibres which are derived from the popliteus tendon.

(4) *Wrisberg's Ligament.*—This, in its commonest form, is a rounded bundle of fibres, ovoid on section at its femoral attachment, which passes from the outer side of the inner condyle to be directly continuous with the fibres of the external semi-lunar cartilage.

It appears to be present in one or other of two varieties:—

(1) In which it may be a well-defined rounded bundle, attached either close to, or about ½ inch from, the oblique fibres. In the former instances it is usually connected by some easily separable connective tissue to the oblique portion, in the latter it is free.

The long axis of its femoral attachment is either in a line more or less parallel with that of the oblique fibres, or else it may make an angle with them.

(2) In this second variety the outermost fibres of the oblique portion are found directly continuous with the fibres of the external semi-lunar cartilage.

Both these varieties are occasionally united with the popliteal contribution.

(4β) The posterior cornu of the external semi-lunar cartilage constantly divides into two bundles of fibres, one of which is attached to the tibia, the other passing obliquely across the anterior surface of the posterior crucial ligament, and the posterior superior tibio-fibular ligament immediately in front of it. These constitute Humphry's crucial ligament, and it is attached to the internal condyle of the femur.

The fibres forming this ligament may comprise nearly the whole of those of the posterior cornu, or only a few of them. Most commonly the two divisions are equal.

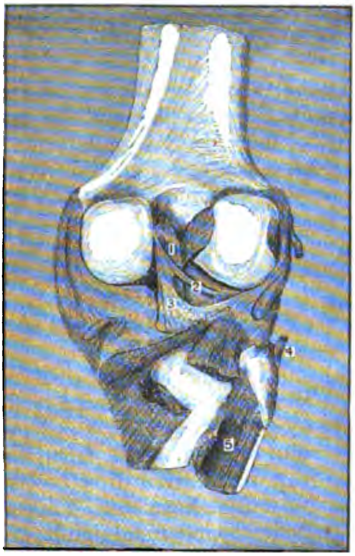
Humphry's ligament is connected to the posterior crucial by some easily separable fat and loose connective tissue, and is bound down to it by the synovial membrane.

(5) *The Posterior Superior Tibio-Fibular Ligament* can be easily demonstrated to be continuous with the fibular origin of the soleus.

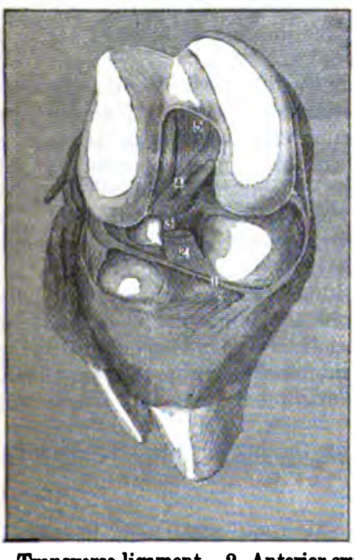
At the apparent attachment of this ligament to the tibia, the bone is crossed by the tendon of the popliteus, and in consequence is grooved and covered with cartilage.

By forcibly tearing the tibio-fibular ligament, it is found that the fibres have been covered with a layer of cartilage, and are continuous with the fibres of the posterior crucial ligament.

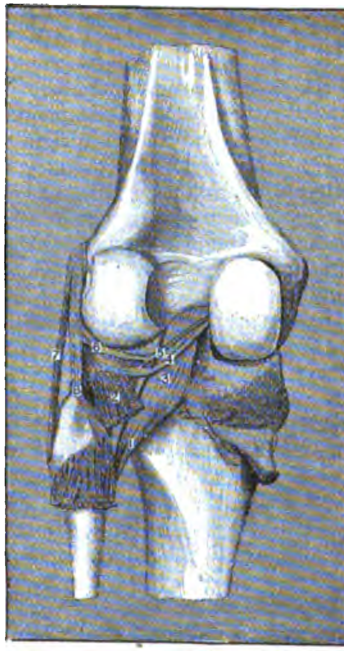
(6) *The connection with the Periosteal Ligaments.*—A portion of the oblique fibres have the appearance of flowing over the smooth grooved interarticular space, and spreading out into the well-marked periosteal ligaments which are found at the back of the tibia, above the soleal line.



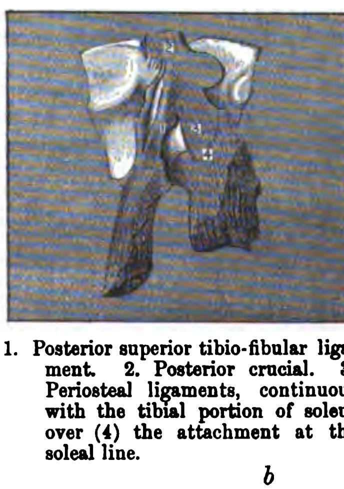
1. Straight portion of posterior crucial ligament. 2. Wrisberg's ligament. 3. Oblique portion of posterior crucial ligament. 4. Long external lateral ligament. 5. Soleus.



1. Transverse ligament. 2. Anterior crucial. 3. Posterior cornu of external semi-lunar cartilage. 4. Humphry's ligament. 5. Posterior crucial ligament.



1. Posterior superior tibio-fibular ligament. 2. Popliteus. 3. Oblique portion of posterior crucial ligament. 4. Fibres of Wrisberg's ligament connected with popliteus. 5 and 6. Fibres of Wrisberg's ligament connected with short external lateral ligament and external semi-lunar cartilage. 6. Fibres passing to short external lateral ligament only. 7. Long external lateral ligament. 8. Short ditto.



1. Posterior superior tibio-fibular ligament. 2. Posterior crucial. 3. Periosteal ligaments, continuous with the tibial portion of soleus over (4) the attachment at the soleal line.

An actual continuity of the crucial fibres can usually be demonstrated; the periosteal ligaments cease at the soleal line, and are continuous with the fibres of origin of the soleus.

(7) *Fibres from the Coronary Ligament.*—The under margin of the external semi-lunar cartilage is attached to the fibula and tibia by a strong band of fibres, which usually pass internally and on a deeper plane to those of the posterior crucial. The continuity of this band is interrupted by an ovoid deficiency, produced by the pressure of the popliteus.

In one of the two specimens there are distinct bands of fibres passing from these capsular fibres to the posterior crucial. In one or two others the fibres previously blend with the irregularly disposed fibres already mentioned, which are found on the outer side of the posterior crucial ligament.

(9) In one specimen there were some fibres derived from the posterior cornu of the external semi-lunar which were directly continuous with the straight fibres of the post-crucial ligament. Further investigation which I hope to make on animals and fœtal joints will probably furnish some explanation of the fibrous contributions I have enumerated.

If comparative anatomy and embryology permitted, it would be tempting to interpret the continuity of the periosteal ligament, with the soleus and the posterior crucial, as evidence of an original origin of that muscle from the femur; but as the soleus is in all terrestrial vertebrates essentially a leg muscle, it is probable that this is rather an upward extension, coincident with the increase of some of the calf muscles associated with bipedal progression.

Humphry's ligament and the disconnected form of Wrisberg's ligament (both of which can be demonstrated to be directly continuous with the fibres of the external semi-lunar cartilage), taken in connection with the occasional continuity of the anterior cornu of the external semi-lunar with the anterior crucial, might be thought to show that the external semi-lunar was originally derived from the spreading out of the primitive interarticular fibrous mass, consequent on the withdrawal of the fibula from articulation with the femur.

But the embryology of the semi-lunar cartilages points to their primary connection with the capsule of the joint, and these uniting bands would therefore seem to be specialised derivatives of the attachment of the primary capsule to the interarticular fibrous mass which separates the outer and inner condylarthrodial joints, of which the knee-joint primarily consists.

I am indebted to Mr F. C. Kempson for his kindness in drawing several of my dissections.

Sir George Humphry's Notes on the Idiot Skull will be found printed *in extenso* in the *Jour. of Anat. and Phys.*, January 1895.

Dr Arthur Keith's paper on the Growth of Brain in Man and Monkeys will be found printed *in extenso* in the *Jour. of Anat. and Phys.*, January 1895.

PROCEEDINGS OF THE

ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

FEBRUARY 1895.

An Ordinary Meeting was held on Wednesday, February 13th, at St Bartholomew's Hospital. Present—Professor D. J. Cunningham, F.R.S. (President), in the chair, forty members and visitors.

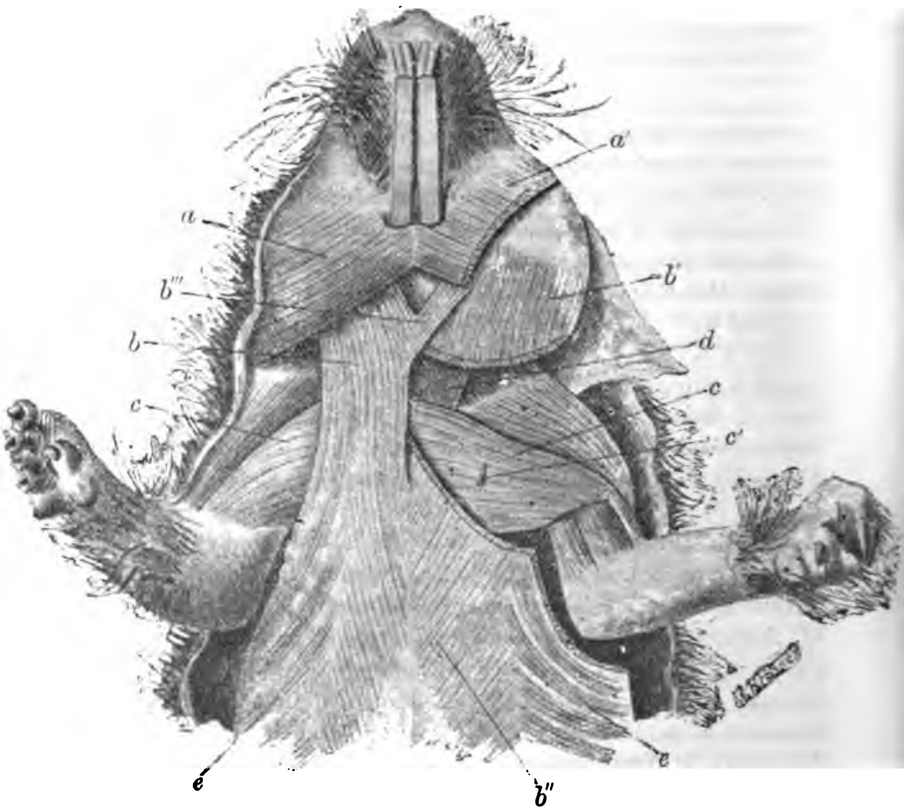
The minutes of the previous meeting were read and confirmed.

The following nominations for Membership were announced:—F. Jaffrey, M.R.C.S., Demonstrator of Anatomy, St George's Hospital, proposed by G. R. Turner, H. D. Rolleston, H. B. Grimsdale; E. C. Stabb, F.R.C.S., Junior Demonstrator of Anatomy, St Thomas' Hospital, proposed by W. Anderson, G. H. Makins, F. G. Parsons; Dr C. C. Baxter Tyrie, Demonstrator of Anatomy, Yorkshire College, Leeds, proposed by Wardrop Griffith, Alex. Macalister, Percy Flemming; Dr Curtis, Demonstrator of Anatomy, University College, London, proposed by G. D. Thane, G. B. M. White, Percy Flemming; A. Y. Richardson, M.B., B.S., Demonstrator of Anatomy, University of Durham College of Medicine, proposed by Robert Howden, Arthur Thomson, Percy Flemming; John Evans, M.D., Demonstrator of Anatomy, University College, Liverpool, proposed by A. M. Paterson, G. D. Thane, Percy Flemming; J. M. Grünbaum, St Thomas' Hospital, proposed by Wm. Anderson, G. H. Makins, F. G. Parsons; J. A. Hayward, M.D. (Lond.), Assistant Demonstrator of Anatomy, St Bartholomew's Medical School, proposed by H. J Waring, T. W. Shore, Percy Flemming.

The following gentlemen were declared duly elected Members of the Society:—Christopher Addison, M.D., B.S., Demonstrator of Anatomy, Sheffield School of Medicine; Dr St George Mivart, F.R.S.; A. N. Weir, Demonstrator of Anatomy, St Bartholomew's Hospital.

Mr F. G. Parsons exhibited a specimen of *Possible Sternalis Muscle in Bathyergus maritimus.* In this rodent there was a large muscle running backwards from the fascia over the masseter to the super-

ficial surface of the pectoral, near the posterior margin of which it blended with the fibres of the abdominal panniculus carnosus. Its nervous supply was possibly from the anterior cutaneous branches of the intercostal nerves which pierced it, and certainly from a twig of the anterior thoracic nerve which entered its deep surface after passing through the pectoral. Mr Parsons regarded this muscle as the sterno-facialis, and pointed out that in Bathyergus it had the same position, direction of fibres, and nervous supply



EXPLANATION OF FIGURE :—

a, Platysma ; *b*, sterno-facialis muscle ; *b'*, sterno-facialis cut ; *b''*, sterno-facialis cut ; *b'''*, fibres decussating in mid line, foreshadowing the sphincter colli of the Primates ; *c*, pectoral muscle ; *c'*, branch of anterior thoracic nerve supplying the sterno-facialis ; *d*, sterno-mastoid muscle ; *e*, superficial fibres of the abdominal panniculus carnosus continuous with the sterno-facialis.

as the sternalis of man. Further, that, if in man the cervical part of this muscle could be supposed to have fused with the subjacent sterno-mastoid, the frequence with which the sternalis

appears as a downward prolongation of that muscle would be explained.

Professor CUNNINGHAM referred to a paper published in *The Journal of Anatomy and Physiology*, in which Dr DOBSON had described a similar muscle in the golden mole of Cape Colony. Dr Dobson was under the impression, however, that in this case the muscle in question was not the sternalis but a displaced rectus abdominis—the displacement of the latter muscle being due to a special development of the pectoral muscles in connection with the burrowing habits of the animal.

He maintained that it was impossible to draw a sharp line of demarcation between the muscular stratum known as the panniculus and the deeper layer of muscles. In all cases where the panniculus is strongly developed, it assumes in certain places deep relations, and obtains skeletal attachments.

He held that the obliquus abdominis externus, the great pectoral, and the sterno-mastoid are muscles which belong to one and the same muscular layer. The fibres of the pectoral part of this stratum have become deflected outwards through the growth of the limb. The sternalis, he believed, consists of some of the pectoral fibres rotated out of their usual position, so as to assume a direction more or less parallel to the long axis of the body.

The nerve of supply from one or other, or from both of the anterior thoracic nerves, showed the pectoral connections of the sternalis. In the numerous cases (now over thirty) of the sternalis muscle which he had seen he had never failed to get this nerve of supply, when his attention was called to the anomalous muscle before the surrounding parts were disturbed.

The discovery by Dr Parsons, in Bathyergus, of a nerve of supply to the muscle in question from one of the thoracic nerves, is most important and interesting. It served to associate the muscle with the deeper muscular stratum, and, to his mind, it constituted the strongest evidence that Dr Parsons had brought forward in favour of the view of regarding the muscle in question as a possible sternalis.

The fact of the intercostal nerves piercing the muscle in Bathyergus means nothing. They do so in the case of the pectoralis major, and yet they do not supply the muscle; they do so in many cases of largely-developed sternalis in man, but it is extremely doubtful if they ever give filaments to the muscle as they traverse it.

Dr KEITH said, that although this muscle had received the attention of nearly every eminent anatomist of recent years, and had acquired a very considerable literature, yet this was the first time a muscle had been demonstrated in a mammalian animal, agreeing with the *Sternalis* of man in position and nerve supply. It is true, however, that Professor Le Double had quoted authority for such a homologue existing in the Giraffe, but the account which Professor Owen gave of that animal's anatomy did not substantiate the statement. The *Sternalis* of man agrees with a large number of human anatomical variations in recalling not *primate* characters, but features

found in animals occupying a comparatively low position in our classificatory system. On the theory of Descent, the demonstration of such a muscle in one of the Rodeutia may provide a morphological basis in which the sternalis may develop in any mammal, but it did not explain the actual resurrection of the muscle in certain individuals. Moreover, there was no *a priori* reason for denying to connective tissue in any part of the body, under certain conditions, the power of developing muscular tissue.

It was a peculiar fact, that out of over one hundred dissections of anthropoid apes with which he was familiar, the sternalis had not been observed once, while in a similar number of men it would have occurred about five times. Evidently the appearance of this muscle in man was connected somehow with the strained condition into which the sternal region of the chest was thrown by the human adaptation to pedal locomotion. It may be a muscle making its way into the orthodox catalogue of human anatomy, but an explanation of its frequent occurrence in anencephalic fœtuses was not in any way forwarded by such considerations.

Professor Wardrop Griffith read a paper on *A case of congenital malformation of the Heart with lateral and antero-posterior transposition of the Aorta and Pulmonary Arteries.*

F. W., a male child, aged eleven weeks, was brought to my out-patient department at the Leeds General Infirmary, suffering from diarrhœa. The child was found to be markedly cyanosed, and the mother stated that it had been so from birth. The veins of the face and head were enlarged. The cardiac action was forcible, and there was evidence of slight hypertrophy, but no bruit could be made out on careful and repeated examination. On several occasions when seen, the child seemed moribund, and it succumbed to a slight intercurrent attack of bronchitis four weeks after I saw it first.

The anomalies found on autopsy were confined to the thoracic organs. There was no transposition of the abdominal viscera. The lungs were not transposed, thus the right lung presented all the characters proper to it, having a third lobe, and being provided with an eparterial bronchus. The left lung had a peculiarly shaped upper lobe, with a great exaggeration of the normal deficiency at its lower and anterior part, but in other respects it had the normal appearances of a left lung.

The heart was found somewhat enlarged, the ventricular part being especially bulky. The apex, which was formed entirely by the left ventricle, was directed rather less to the left than normally. The two auricles presented the usual appearances externally, with natural and well-formed appendices, the right receiving the superior and inferior venæ cavæ, the anatomy of which vessels was normal, and the coronary sinus, which lay as usual in the posterior auriculo-ventricular furrow of the left side, and the left receiving as normally the four pulmonary veins.

The foramen ovale was widely patent, the main deficiency being above and in front of the valve, which presented the usual crescentic

free margin, and which also had a deficiency at its upper and anterior part; the main aperture readily admitted the passage of the handle of a scalpel.

On opening the ventricular cavities, they were found to communicate freely with one another by a large aperture at the upper part of the septum, admitting of the passage of a pencil, and limited below by a smooth crescentic rounded margin. The posterior boundary of the opening was continued up as a thin fibrous membrane, and blended with the upper part of the septal flap of the right auriculo-ventricular valve, which, as will be seen, it separated from the orifice of one of the vessels arising from the ventricular cavity. There was thus an absence of the *anterior* part of the undefended area, of the part, that is, which is developed from the aortic bulb septum, while the posterior part, derived, according to His, from a septum intermedium, was normally developed.

Into the two ventricles, thus imperfectly cut off from one another, there opened the right and left auricles respectively, whose orifices were guarded by valves, which, though somewhat modified, presented on the right side the characters of a tricuspid, and on the left side, those of a mitral valve. The arrangement of the papillary muscles, and the appearances of the columnæ carneæ were in harmony with there being no transposition of ventricles. It was interesting to observe, as I have noted in other cases, that the chordæ tendineæ for the contiguous margins of the great anterior and septal flap were attached to the upper and back part of the imperfect septum.

Coming off from the upper and anterior part of this common ventricle, but having a more direct and manifest connection with the right than with the left, was a large vessel. This lying in front, and coming more especially from the right ventricle, one would have expected to be a pulmonary artery, but the following points were noted in connection with it:—

1. It arched backwards over the root of the right lung, and was continued down the back of the chest.

2. It gave off an innominate artery to the left side, followed by a right carotid and by a right subclavian.

3. From opposite the upper part of the anterior sinus of Valsalva there came off a large artery, which at once divided into branches, having the normal distribution of the right and left coronaries respectively.

4. Coming from it just beyond the right subclavian was a patent ductus arteriosus (fig. p. xvi.), which opened into the right bifurcation of the vessel noted below as going to the lungs. Round the vessel on the distal side of the ductus arteriosus there hooked the right recurrent laryngeal nerve.

5. The semilunar flaps were well developed and the adjacent parts of the two posterior were continuous with the anterior mitral flap. The anterior semilunar flap was separated by a considerable area of fleshy "conus" from the tricuspid valve; but the commissure of the anterior and septal flaps of the tricuspid valve was continuous, along with the posterior falciform edge of the ventricular septum, with the

postero-right semilunar flap immediately to the right of the orifice of the vessel destined for the lungs.

The lungs got their blood supply partly through the patent ductus arteriosus, partly, and to a slightly greater extent, through a vessel having the mixed characters of an aorta and pulmonary artery. Pulmonary it was in dividing into branches for the lung, and, making allowance for lateral transposition, in receiving by its right branch

a ductus arteriosus. Aortic it was in arising from the ventricular cavity behind the large artery which has been described. The opening from the ventricle was small, and situated below the postero-right semilunar flap of the large vessel, and between the posterior part of the large mitral segment and the extreme upper part of the interventricular septum, which here shaded off on to the posterior wall of the ventricular cavity, and separated the opening of the vessel under discussion from the septal flap of the tricuspid.

On opening the vessel, as seen in figure, its valvular arrangement was seen to consist of a bicuspidate cone with the long axis of the opening running from above downwards and forwards. Of this the posterior commissure was attached to the wall of the artery, while the anterior was free within its lumen. The lips of the opening were sinuous, and external to the free part of the cone there was slight dilatation of the vessel as of a rudimentary and undivided sinus of Valsalva. The distance from the ventricular opening to the apex of the cone was $\frac{1}{3}$ of an inch.

The patency of the foramen ovale, and the incomplete character of the interventricular septum in this case, follow naturally on the imperfect development of one of the large vessels arising from the ventricular part of the rudimentary heart.

The chief point I wish to emphasise is the lateral, and especially the antero-posterior transposition of the two main vessels without any corresponding lateral transposition of the ventricles. I attempt no explanation of the anomaly, though a partial one may be found in the suggestion that the aortic bulb septum had "forgotten" its usual spiral twist.

Professor G. B. Howes pointed out that the heart under consideration appeared to him, especially in the relationship of its arterial roots, to present a close similarity to that of the lower Reptilia. In the Monitors and Snakes the pulmonary artery arises to the left of the aortæ and of the ventricular cavity, in contradistinction to the higher Sauropsida, in which, as in Mammals, it curves round the bases of the aortæ, and reaches the right ventricular border. Comparison of the hearts of a Monitor, a Snake, and a Chelonian appeared to him to render it in the highest degree probable that the cavum venosum (right ventricular cavity of the higher amniota) represents the entire ventricular cavity of the Amphibia, and that to extension of the right-hand cornu of this the formation of the cavum arteriosum and of its ultimate derivative, the chamber of the left ventricle, has been due. This extension, at first feeble and confined (*Monitor*) to the postero-dextral region of the ventricle, enters the entire posterior region (*Snake*), and finally reaches the left side (*Chelonian*), the pulmonary artery and cavum venosum, which originally occupied the ventro-sinistral region, being pushed to the right side in its advance. If this be so, the formation of septum ventriculorum of the Reptilia, and its homologue in Man, the "septum inferius" of His, would appear to have been primarily due to extension of the ventricular cavity into the posterior cardiac wall, rather than to ingrowth of the latter, as is commonly supposed. The septum would appear to have become rotated forwards as the extension of the ventricular cavity increased, and in its right-hand face we would seem to be dealing with the homologue of the postero-internal face of the Amphibian's ventricle. For these reasons, he thought (1) that comparison of the heart exhibited by Professor Griffith with that of the lower Sauropsida[1]

[1] Magnificent dissected specimens of these are in the Museum of the Royal College of Surgeons, especially the heart of *Varanus salvator*, Cat. No. 917G.—G. B. H.

might reveal points of structural similarity, and might show that the former differs from the normal human heart as the latter does from that of the higher Sauropsidon; and (2) that the heart exhibited, like that of the Monitor, would appear to have stopped short at an approximately Amphibian stage in evolution.

Professor CUNNINGHAM exhibited *Three Skulls from New Guinea* and *two* from the *Torres Straits* (*Island of Mer*). These skulls, with many others, had been brought home by Professor Haddon, and most generously placed by him in the Anthropological Department of Trinity College. The three New Guinea skulls showed wounds produced by the stone axe in use by the natives of that country. The injuries were all inflicted from behind, and in every case they had proved fatal. These injuries are of such a kind that, by a study of them, we are able to form a very vivid picture of what had taken place in each case while the tragedy was being enacted. It is clear that the victims, in every instance, had been attacked in the most cowardly manner, and probably while unarmed. One of the skulls on the table had belonged to a woman, and it was clear that she had made a run for life: the head injuries showed this.

The Mer skulls showed injuries produced by the stone club used by the natives. In one of the specimens the whole side of the cranium had been driven inwards and greatly comminuted; nevertheless, recovery had taken place, and the fragments were united like a piece of mosaic work.

Professor HADDON exhibited two *stone weapons* used by the natives of New Guinea.

Professor CUNNINGHAM read a paper, illustrated with lantern slides, on *Pithecanthropus erectus*, the man-like transitional form of Dr Eugene Dubois. He stated that he had no doubt that the skull and femur were both human.

Dr KEITH said that the tooth, femur, and part of skull, from which M. Dubois had drawn such a full inference, were found in the bed of the Bengawan. This appeared to be a typical tropical stream, rising in the mountains near by, a dry channel during the hot season and a turbulent voluminous torrent during the rainy months, churning and overturning its bed and banks. It was thus evident that the bones need not belong to the same animal, and that their position gave no clue to their antiquity.

He agreed entirely with Professor Cunningham concerning the femur, but regarding the tooth, although he could produce no evidence absolutely negativing its being human, yet there were grounds for believing it was not. That it was an upper third molar of the right side there was no doubt; and the fact that both posterior cusps were feebly developed, indicated that it possessed an antero-posterior diameter considerably less than the two molars standing in front of it. The other teeth being in proportion, the animal that possessed that tooth must have had a bony palate measuring over

85 mm. in length, and been furnished with very large temporal muscles. Now, Dr Dubois' skull showed only faint indications of rather small temporal muscles, so that one concluded the skull and tooth belonged to different animals. This conclusion was the more readily arrived at seeing that the tooth in question resembles closely the very variable third molar of the Orang. He held that the crenation of the posterior fringe of the tooth, taken along with its shape and dimensions, was practically diagnostic of its being an Orang's tooth. If he were right in that, and if Dr Dubois could guarantee his Malay coolies that made his excavations, then this find may be taken as evidence of the former existence of the Orang in Java.

As to the skull, although it was probable that Professor Cunningham's interpretation was the right one, yet the strong keeling along the metopic and anterior part of the sagittal sutures suggested to him that the bones found themselves in a position to expend a good deal more osseous matter after the brain had ceased to make any demand upon them, so that, in his opinion, similar specimens from the same locality were requisite to give assurance that it was the skull of a normal individual.

Professor SHERRINGTON read a paper *On the distribution of the Sixth Lumbar Nerve of Macacus rhesus.* If the distribution of the sixth lumbar nerve be examined in the limb of *Macacus rhesus* great topographical discrepancy is apparently existent between the distribution of the filaments belonging to the sensory root of the nerve and those belonging to the motor root. In view of the light that may be thrown upon the segmental architecture of the limb by tracing the distribution of the spinal nerves in it, this discrepancy possesses interest.

Subject to a not inconsiderable degree of individual variation, the distribution of the motor root of the nerve in question I have found to include the following muscles:—some axial muscles in the back, gluteus medius, pyriformis, quadratus femoris, semimembranosus, biceps, semi-tendinosus, tibialis anticus, extensor longus digitorum, extensor hallucis, peronei, extensor brevis digitorum, popliteus, plantaris, flexor longus digitorum, tibialis posticus, flexor longus hallucis, soleus, gastrocnemius (slightly only), flexor brevis digitorum, abductor hallucis, flexor brevis hallucis, lumbricales. This muscular field of distribution of the motor root is seen to include muscles in the attached base of the limb, in the thigh, in the leg, and in the foot. The motor root of the sixth lumbar may be said therefore to innervate a ray of muscular tissue extending from the trunk outward along the length of the limb into the apex of it.

On the other hand, the sensory root of the nerve, when its distribution in skin is examined, is found to possess a field that includes the whole of the foot, the back of the leg, and the back of the ham; it is distributed, therefore, to the apical part of the limb, but not to the attached base of the limb.

Is this discrepancy between the arrangement of distribution of the

sensory and motor components of the spinal nerve in the limb to hold good when *the sensory nerves to muscles*, which I have shown to be numerous, are included in the analysis? It does not. I find the sixth lumbar nerve giving sensory filaments to the following muscles:—gluteus medius, pyriformis, muscles of the back (*via* posterior primary division of the nerve), hamstring muscles, quadratus femoris, tibialis anticus, tibialis posticus, flexor longus digitorum, flexor longus hallucis, peronei, flexor brevis digitorum, extensor brevis digitorum, abductor hallucis, and soleus. I have no doubt the list of muscles could be extended were a greater number of observations made, so as to include a greater range of individual variation.

Specimens were shown illustrating the *sensory* fibres in the posterior primary division of the nerve (to which no cutaneous branch had been discoverable by dissection), also in the nerves to the hamstring muscles, tibialis posticus, soleus, and flexor brevis digitorum muscles.

PROCEEDINGS OF THE

ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

MAY 1895.

An Ordinary Meeting of the Society was held on Monday, May 13th, at St Thomas's Hospital Medical School, Sir G. Murray Humphry in the chair. Present—Thirty members and visitors.

The following gentlemen were declared duly elected members of the Society. F. Jaffrey, M.R.C.S., Demonstrator of Anatomy, St George's Hospital; E. C. Stabb, F.R.C.S., Junior Demonstrator of Anatomy, St Thomas's Hospital; Dr C. C. Baxter Tyrie, Demonstrator of Anatomy, Yorkshire College, Leeds; Dr Curtis, Demonstrator of Anatomy, University College, London; A. Y. Richardson, M.B., B.S., Demonstrator of Anatomy, University of Durham College of Medicine; John Evans, M.D., Demonstrator of Anatomy, University College, Liverpool; J. M. Grünbaum, St Thomas's Hospital; Dr J. A. Hayward, Assistant Demonstrator of Anatomy, St Bartholomew's Medical School.

The following were nominated for election at the next meeting:—Mr Hubert Higgins, proposed by Alexander Macalister, G. M. Humphry, and Percy Flemming; Mr Geo. S. Farmer, M.B. (Oxon.), F.R.C.S., proposed by Arthur Thomson, G. M. Humphry, and Percy Flemming.

The Secretary announced that the President was prevented by an important meeting in Dublin from attending the meeting.

The Secretary read, for Professor D. J. Cunningham, a paper *On the Form of the Spleen and Kidneys;* which will be found printed *in extenso* in the *Journal of Anatomy and Physiology*, p. 501.

Professor A. M. Paterson showed two examples of *Adult Diaphragmatic Hernia.*

Case 1. Male, aged 67, from the Anatomy Rooms of University College, Dundee.

The hernia projects through the diaphragm into the right pleural sac. The neck of the sac is a well-defined opening in the diaphragm, 3½ inches laterally, 2½ inches from before backwards. It is placed anteriorly, a little to the right of the middle line; and is bounded anteriorly by the ensiform cartilage and right costal arch,

posteriorly by the central tendon of the diaphragm; on the right side it is limited by a fold of peritoneum, continuous with, and forming part of, the falciform ligament of the liver. The sac of the hernia is lined by peritoneum, and is separated into a large right and a smaller left portion by a septum, with a sharp concave lower border, which projects downwards towards the abdominal cavity. This septum may be due to the partial union of two sacs, separated from one another by a slip of the diaphragm. The contents of the sac are omentum and 15–18 inches of transverse colon. The omentum is adherent to the bottom of the right half of the sac. On examining the thorax, the hernia is found to occupy the right pleural sac, in the angle between the pericardium and diaphragm, and in front of the inferior vena cava. Covering the sac is diaphragmatic pleura, separated from the peritoneal lining by cellular tissue and a tough membrane, in which are vestiges of muscular tissue derived from the diaphragm.

Other abnormalities were found in this subject:—(1) On each side, a small, reducible, oblique inguinal hernia. In each case the sac reached as far as the top of the tunica vaginalis of the testis. (2) Peritoneal peculiarities: The cæcum, ascending colon, and the transverse colon as far as the loop entering the hernial sac were enormously distended. The rest of the large intestine, on the other hand, was empty and attenuated. The whole of the large intestine possessed a separate mesentery. There was no hepatic flexure—The ascending and descending colon, with the lateral parts of the transverse colon, were attached to the parietes directly. The vesical part of the transverse colon, including the herniated portion, had a peritoneal attachment to the great omentum, which was thus laterally connected directly to the abdominal wall; in the middle line, by a connection common to it and the transverse colon.

Case 2. Female, aged 46, from the Anatomy Rooms, University College, Liverpool. The cause of death was cardiac syncope.

On opening the abdomen, the cavity was found to extend upwards in the left side as high as the third rib, which could be felt with ease. The case at first sight bore a suspicious resemblance to a congenital deficiency of the left half of the diaphragm. The cavity communicated with the general cavity of the abdomen by a wide opening, bounded anteriorly, posteriorly, and in the left side by the parietes. On the right side, extending from a point anteriorly a little to the left of the ensiform cartilage, to the spine posteriorly, the opening was bounded by a sharp concave edge, formed by the diaphragm, covered by peritoneum. The sac of the hernia was lined by peritoneum throughout, and on its right side the heart and pericardium, on its left side the thoracic, could be felt. The contents of the sac were, a portion of stomach (cardiac end), the colon (part of transverse splenic flexure, and descending), and the spleen; the last named being kept in position by a well-marked splenico-phrenic ligament. There was no indication to be made out of the presence of a left lung in relation to the hernial sac, by examination from the abdomen.

In the abdominal cavity, one of the most striking features present was the increased length and enormous distension of the descending colon and rectum. The length of the different parts of the intestine were as follows: small intestine, 28½ feet; large intestine over 7 feet (ascending colon 6 inches, transverse colon 37½ inches, descending colon 7½ inches, sigmoid flexure 29½ inches). The stomach was much dilated, and was cingulated round the concave right border of the neck of the sac; the large intestine was greatly over-distended with scybala; and the rectum filled up the entire pelvic cavity, so as to raise up the bladder, uterus and broad ligaments above the pelvic brim.

On opening the thorax the condition was explained. On removing the upper left ribs a pleural sac was discovered, containing a functional lung, smaller than usual, with a slightly consolidated base and a few pleural adhesions, but otherwise normal. The dome of the pleura in this side extended higher than usual above the level of the first rib. The muscular tissue of the diaphragm, very much thinned out, formed, however, in a continuous stratum, the wall of the hernial sac. It was pushed upwards, in front of the lung, so that a narrow elongated space existed behind it for the reception of the greater portion of the lung.

Regarding the causation of these herniæ one has little to say. The condition of the bowel in each case may have been a consequence of the hernia: in the first case the inclusion of a loop of gut producing partial or complete obstruction of the bowels; in the second case the weakening or loss of power in the left half of the diaphragm may have caused the descending colon and rectum to become over-distended. On the other hand, in the second case, the distension of the bowel may have been a cause of the upward prolongation of the diaphragm.

Mrs E. E. Flemming showed a specimen of *absence of the Left Internal Carotid*. The specimen was obtained from the dissecting-room of the London School of Medicine for Women.

The Vessels.—Three branches come off from the arch of the aorta—viz., the innominate, the left subclavian, and between them a small branch, which has the distribution of the left external carotid. There is no internal carotid on the left side. On the right side the common carotid divides as usual.

The arrangement of the arteries at the base of the brain is as follows:—

The right internal carotid divides into a right middle cerebral, and a trunk which anteriorly divides into right and left anterior cerebral arteries. The basilar artery divides into the right posterior cerebral and a trunk three-eighths of an inch long, which divides into the left posterior cerebral and the left middle cerebral. The latter is connected by a slender branch with the left anterior cerebral, thus completing the circle of Willis. The ophthalmic artery on the left side arose from the middle cerebral.

The bone.—There is no carotid canal in the petrous bone. The

foramen lacerum medium is much reduced in size. A long groove for the large superficial petrosal nerve leads to that portion of the foramen which is external to the lingula, while internal to the lingula is a small foramen, and a shallow bay between it and the petrous process of the sphenoid, but no carotid groove, as on the other side.

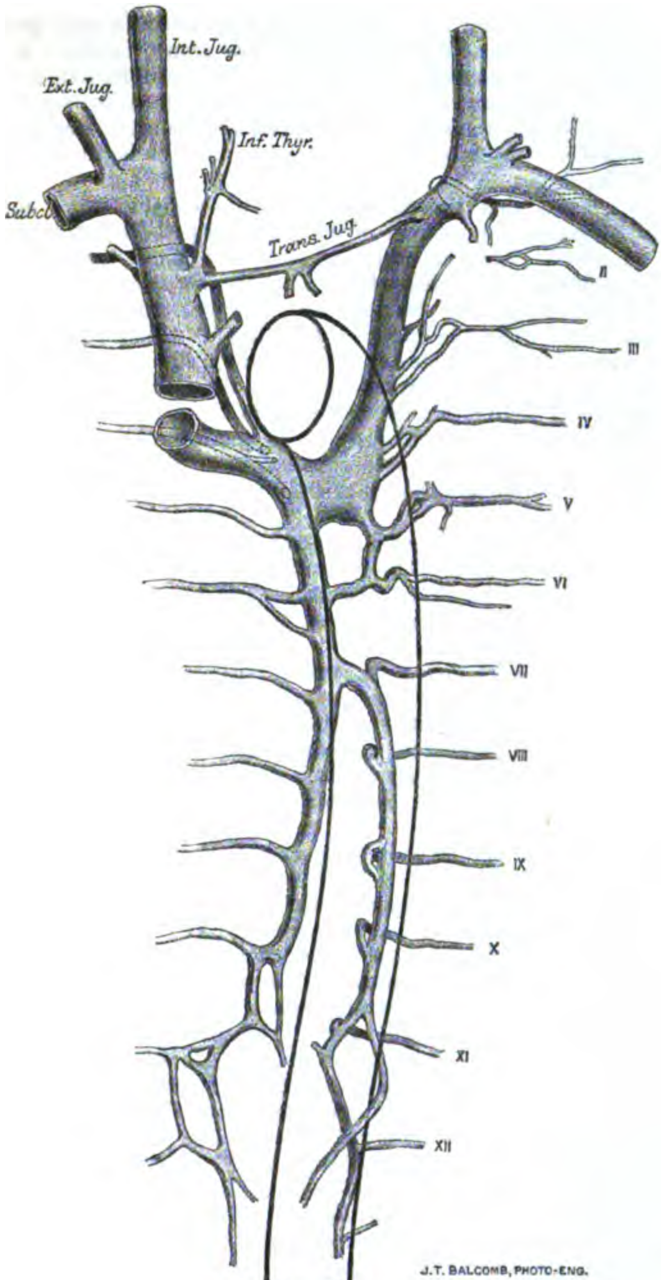
Prof. THANE has kindly given me four references of absence of one internal carotid artery. In Wyeth's case (*Essays in Surgical Anatomy and Surgery*), the left internal carotid was absent, and there was no carotid canal. No details were given of the anastomoses. Wyeth refers to "a very analogous" case in *New York Med. Record*, vol. xi. [Eugene Peugnet], and also mentions that Koberwein had seen a skull with only one carotid canal.

Quain, in his *Commentary*, records a case with no internal carotid and no carotid canal on the left side. The internal maxillary artery sent branches through the foramen ovale and the foramen rotundum on the left side, also the right internal carotid artery was larger than usual.

In the fourth case (referred to by Quain and Henle), the right internal carotid was absent, and there was a small carotid canal, through which a bristle could be passed. No account of the anastomoses was given.

Quain's specimen referred to above was exhibited at the meeting, owing to the courtesy of the Curator of the Museum, University College, London, where the specimen is preserved.

Mr HART-SMITH showed a specimen of *abnormal Left Innominate Vein.* On the left side, the internal jugular and subclavian veins join to form an innominate or brachio-cephalic trunk. From this trunk a small branch, which is pervious, and receives some small thymic tributaries, passes across, in the usual position of the left innominate vein, to join the right innominate. The main brachio-cephalic trunk of the left side passes backwards on the left of the subclavian artery, and then turns downwards behind the dorsal extremity of the arch of the aorta, where it takes up the position of the normal left superior azygos vein. The trunk is continued downwards behind the aorta to the level of the fifth dorsal vertebra, receiving in its course tributaries from the second, third, fourth and fifth intercostal spaces of the left side. Over the fifth dorsal vertebra the trunk becomes enlarged, and turns sharply to the right behind the œsophagus, to join the large azygos vein. The large azygos vein passes upwards from the diaphragm, occupying its usual position in the posterior mediastinum, and receiving tributaries from the intercostal spaces of the right side. Opposite the seventh dorsal vertebra it is joined by the left lower azygos vein, which drains the spaces of the left side as high as the seventh, and then it receives separately the termination of the sixth intercostal vein of the left side, which also has a free communication with the vein of the fifth space, just before the latter opens into the dilated trunk of the left side.



Abnormal Left Innominate Vein.

Over the fifth dorsal vertebra the right azygos vein becomes greatly enlarged by the junction of the left superior trunk, and then arches forwards in the usual manner over the root of the right lung to join the superior vena cava, which only then acquires its customary size.

The intercostal veins from the second and third spaces of the right side open separately, but close together, into the beginning of the arch of the azygos.

It is evident that the anomalous brachio-cephalic trunk of the left side occupies the position of the proximal portion of the normal left superior intercostal vein and the left upper azygos vein. Developmentally, it has been formed by the persistence and dilatation of the connection between the left primitive jugular and cardinal veins, while the duct of Cuvier has been obliterated in the usual manner. It is noteworthy that the utilisation of this circuitous course for the return stream from the left side of the head and left upper limb is not dependent upon the absence of the communication between the two primitive jugular veins; for, as in most cases of so-called double superior vena cava, the transverse jugular vein is present, although of small size.

Mr W. S. Melsome showed a specimen of *Hour-glass Stomach, with peculiar Pyloric Orifice.* The stomach was taken from a dissecting-room subject (a sailor from Norway). The shape of the various parts is indicated in the accompanying drawing, which was made after inflating with air.

The constricted portion at A, which separates the primary from the secondary stomach, admits one finger. There is no thickening, or any sign of obstruction at this point.

The œsophageal opening (*o*) also admits one finger, but less readily.

The capacity of the primary stomach P, S, is 300 c.c. Its muscular coats are considerably hypertrophied. The spleen, S, is attached to its cardiac end.

The capacity of the secondary stomach, S, S, is 475 c.c. Its coats are not hypertrophied.

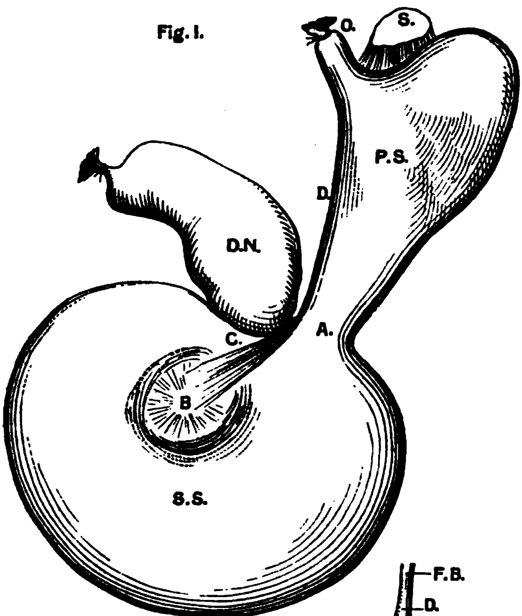
A strong fibrous band runs along the lesser curve, D, of the primary stomach as far as the duodenal orifice, C. Here it splits into two equal parts, which pass obliquely downwards and forwards over the surface of the secondary stomach, the one in front and the other behind, and terminate by becoming intimately blended with a patch of pearly-white fibrous tissue about the size of a sixpence, the fibres of which radiate from a central point, B, fig. 1. These two patches of fibrous tissue are situated at corresponding points on the two surfaces, and the features observed on the front wall are exactly similar to those observed on the back wall. There is no unusual thickening, or any sign of puckering.

The pyloric orifice admits two fingers. It is formed entirely by fibrous tissue, which is quite unyielding. When the fingers are introduced and an attempt is made to separate them, the fibrous ring presents almost a cutting edge.

The ring is formed partly by the two bands which result from

the splitting of the strong fibrous band which runs along the lesser curve of the primary stomach and partly by separate fibres. This is best understood by referring to fig. 2, which gives a diagrammatic

Fig. I.



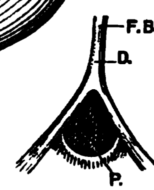


Fig. 2.

representation of the pyloric orifice, P, seen from above, the duodenum having been invaginated into the stomach. That portion of the orifice bounded by the two bands is V-shaped, the opposite portion forms part of a circle.

The stomach was turned inside out and thoroughly examined for previous disease. There is, however, no trace of this, and the mucous membrane is quite normal. The surrounding organs, including the œsophagus, are healthy. There are two spleens: the one indicated in the drawing is about the size of a small walnut, the other is half the weight of a normal spleen.

The Secretary showed, for Mr Bland Sutton, a specimen of *Cotyloid Bone in the Pelvis of the Cat.* It is well known, that the cotyloid bone is a constant feature in the pelvis of Rodentia, and, as in the case of Kangaroos, is of sufficient size to exclude the pubes from the cavity of the acetabulum. Recently Mr H. C. Adams, a student of the Middlesex Hospital, drew my attention to a pelvis

obtained from a cat six months old, in which the cotyloid bone was large and conspicuous. He assures me that he has found it as large in other specimens he has prepared from kittens. In the example before the meeting the cotyloid element is equal in size to the same bone in a young rabbit.

The large size of the cat's cotyloid bone suggests that this morphological element exists throughout the *Felidæ*, and would repay investigation.

Prof. G. B. HOWES pointed out that the cotyloid bone had been already described in the cat by Strauss-Durckheim, in his classical monograph on the anatomy of that animal, published in Paris in 1845; and that a critical résumé of all that was known of the comparative morphology of the bone up to the year 1885 was published by Krause in the second volume of the *Monthly International Journal of Anatomy and Histology*. He remarked that while the cotyloid bone had been discovered in the leading orders of Placental Mammals and in the Marsupialia, it was customary to deny its existence in the Monotremata. Concerning this, however, he had been privileged to lay before the Society a paper in which (this *Journal*, vol. xxvii. p. 550) he had attempted to show that it is in the *Ornithorhynchus* represented in its most extensive known form.

Mr H. F. MACCALLAN read a paper on a *Communication between the Facial and Glosso-pharyngeal Nerves*. During a dissection last term I found a small nerve communicating, through the stylo-pharyngeus muscle, with the glosso-pharyngeal nerve. On tracing it to its origin, I found that it left the facial trunk about 4 or 5 millimetres before the exit of the latter from the stylo-mastoid foramen. After running for about 2 millimetres anteriorly and internally to the facial nerve, but in company with it, it left the aqueductus Fallopii and proceeded in a special canal of its own through the vaginal process of the temporal bone, and appeared at the root of, and internal to, the styloid process.

Continuing its downward course, the nerve lay beneath the anterior border of stylo-pharyngeus muscle lying upon the internal carotid artery and superior constrictor muscle. At the middle of the stylo-pharyngeus the nerve communicated, through the substance of the muscle, with a branch of the glosso-pharyngeal nerve, and from the loop so formed the muscle was innervated. The nerve then ran forwards and downwards, and sent a large branch to the tonsil, which communicated with a tonsillar branch of the glosso-pharyngeal. Proceeding in a forward direction it disappeared under the hyo-glossus muscle, where it terminated in branches to the mucous membrane of the side of the tongue, above the anterior pillar of the fauces, and to the palato-glossus and stylo-glossus muscles. Its terminals again communicated by three or four branches with the terminations of the glosso-pharyngeal nerve.

On reference to anatomical treatises, the only description of such a nerve in the English books I found in Morris, where a similar

one is described in a note taken from Testut. In the work of that author the nerve is described as being of normal occurrence. Cruveilhier in a note describes a similar nerve, on the authority of Sappey. The majority of the authors I referred to who mention such a nerve, seem to describe it either directly or indirectly on the authority of Sappey.

I made corresponding dissections of ten different parts, in order to determine how often this nerve was present.

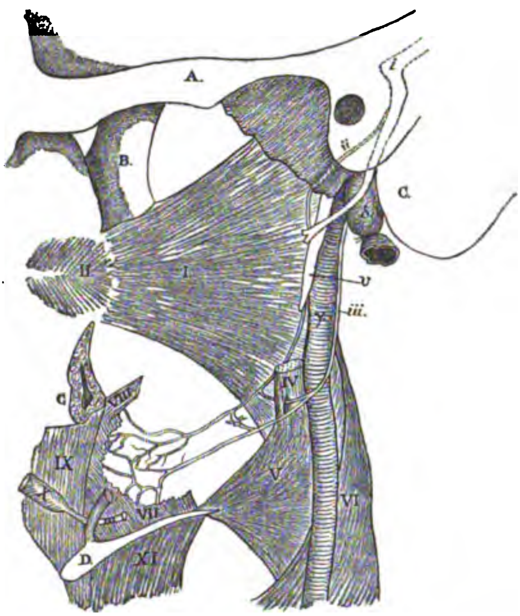


FIG.—A, zygoma; B, external pterygoid plate; C, mastoid process; D, hyoid bone; *v*, styloid process; I, superior constrictor; II, buccinator; III, posterior belly digastric; IV, stylo-pharyngeus; V, middle constrictor; VI, inferior constrictor; VII, hyoglossus; VIII, styloglossus; IX, mylohyoid; X, anterior belly digastric; XI, thyrohyoid; γ, int. carotid artery; δ, int. jugular vein; i, facial nerve; ii, communicating branch described; iii, glosso-pharyngeal nerve. The dotted lines represent the course of the nerves while in the bone.

In two cases I found a branch leaving the facial trunk a few millimetres above the stylo-mastoid foramen, which proceeded in a canal of its own through the bone to reach the inner side of the styloid process.

In two cases a branch left the facial nerve at the stylo-mastoid foramen. The remainder of the description of the nerve in the above four cases would be the same as the description I have given at the beginning of this paper.

In six other cases I found no such anastomosis between the facial

and glosso-pharyngeal nerves. Several authors describe a communication between these two cranial nerves through the posterior belly of the digastricus (Heath, Gray, Quain, Cunningham, Valentin, Cruveilhier). But in none of my cases was I able to find such an anastomosis.

In two of the parts I examined I found more than one branch from the facial nerve to the posterior belly of digastricus: in one of these there were three branches; and in the other, two. In each case they arose separately from the parent trunk. In another case a branch left the facial nerve, a digastrico-styloid branch, which bifurcated, one branch entering the posterior belly of digastricus, and another the stylo-hyoideus.

In a fourth dissection I found one branch to the posterior belly of digastricus from a digastrico-styloid trunk, and another from the facial, arising a little below the digastrico-styloid branch.

In the remaining six cases there was one branch to digastricus and one branch to stylo-hyoideus arising from the parent trunk at the stylo-mastoid foramen. In no case did any of these send a branch through the muscle to the glosso-pharyngeal.

The SECRETARY read, for Mr DIXON, a note on the *connection of the Facial with the Glosso-pharyngeal Nerve.* While studying the distribution and connections of the fifth nerve in the human embryo, I noticed that in an embryo of the eighth week—(Professor His' embryo, *Mr*) the seventh nerve was connected with the ninth by a very well-marked twig. This connecting twig in this embryo lies immediately behind the styloid process, and joins the facial just as the latter gives off its chorda-tympani branch. Traced in the opposite direction, the connecting nerve was found to spring from the proximal or jugular ganglion of the glosso-pharyngeal. The accompanying diagram is a rough sketch of a model reconstructed by drawing the successive sections on glass plates, and then superimposing the plates. The diagram corresponds to a very thick coronal section × 30 diameters.

Lately I have attempted to determine the development and position of this connecting twig in rat embryos, and have found that it is present at a very early period—fifteenth day—in these animals. Just as in the human embryo, the nerve springs in the rat from the jugular ganglion of the glosso-pharyngeal, and joins the facial almost exactly at the point where the chorda-tympani leaves it.

The accompanying sketches from photographs illustrate these facts. The photos are from sections cut as nearly as possible in the plane of the connecting nerve, and are, at the same time, cut horizontally through the head. In the first photo the connecting nerve is seen passing behind the facial and joining its extreme outer part; in the second, the origin of the nerve from the jugular ganglion is more distinctly seen. The connecting nerve lies in front of the large jugular vein. These two photographs are from successive sections. In the fourth section, above that represented by the second sketch, that is, in a section 30 m. above it, the origin of the chorda-tympani nerve is seen,

and in the next section the chorda-tympani has separated from the facial. The chorda-tympani is seen to take origin from the same aspect of the facial that the connecting nerve has joined.

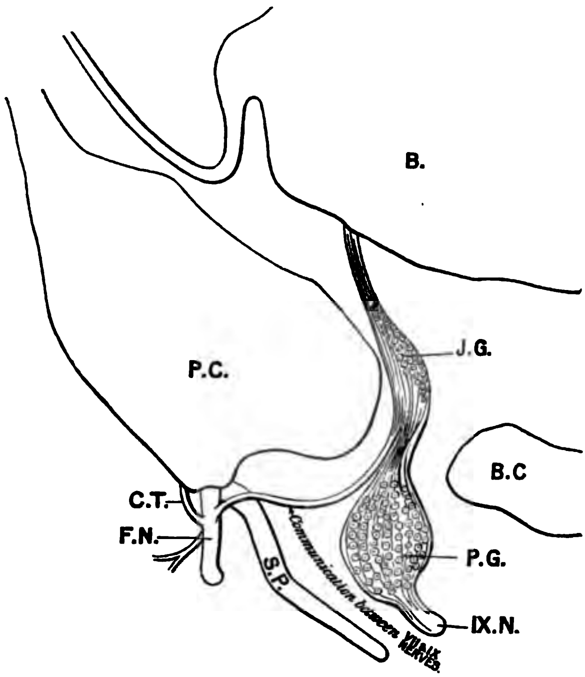
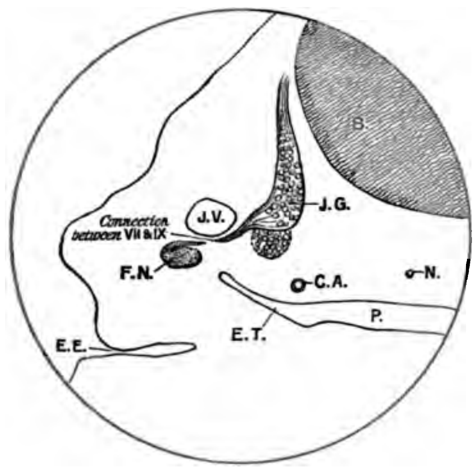


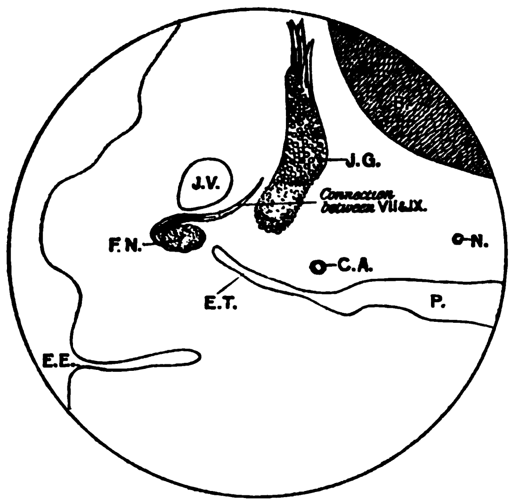
FIG. 1.—Sketch of a portion of a model of the Head of a Human Embryo of the eighth week (Prof. His' embryo *Mr*). The drawing corresponds to a very thick coronal section through a portion of the head. B, brain; P.C, periotic capsule; J.G, jugular ganglion; B.C, basis cranii; P.G, petrous ganglion; C.T, chord and tympani; F.N, facial nerve; S.P, styloid process.

It seems possible that the chorda-tympani may contain fibres derived from the glosso-pharyngeal through this connecting nerve. The chief portion of the chorda-tympani is, however, present before the appearance of the connecting nerve. The communication is found to be present before the muscles supplied by the glosso-pharyngeal and facial nerves appear (Figures, 2, 3, p. xxxii.).

Mr H. HIGGINS' paper on the *Popliteus Muscle* will be found printed *in extenso* in the *Journal of Anatomy and Physiology*, page 569.

Dr D. HEPBURN'S paper on *the Papillary Ridges on the Hand and Feet of Monkeys and Men* was taken as read.





FIGS. 2 and 3.—Outlines of portions of two successive horizontal sections through the head of a Rat Embryo of about fifteen days, to show connection between Glosso-pharyngeal and Facial nerve. B, brain; J.G, jugular ganglion; J.V, jugular vein; F.N, facial nerve; E.E, external ear; E.T, Eustachian tube; P, pharynx; C.A, carotid artery; N, notochord.

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